CONVERSION OF RESEARCH AND TEST REACTORS TO LOW-ENRICHED URANIUM (LEU) FUEL

HEARING

BEFORE THE

SUBCOMMITTEE ON
ENERGY DEVELOPMENT AND APPLICATIONS

AND THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND PRODUCTION

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
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  James Spickard, dated September 10, 1984 1698
  Corey Dzitzer, dated September 12, 1984 1700
  Kayleen Kott, chair, University of California Student Body Presidents' Council, dated September 12, 1984 1701
    Enclosure 1: Student Body Presidents' Council resolution supporting the proposed rule by the Nuclear Regulatory Commission on limiting the use of highly enriched uranium in domestic research and test reactors, dated August 18, 1984 1702
    Enclosure 2: Letter to the Secretary of the Commission, from Kayleen Kott, chair, University of California Student Body Presidents' Council, dated August 29, 1984 1703
  Francis Pinto, dated September 13, 1984 1705
  Olivia Diaz, dated September 14, 1984 1706
  Joan M. Schiessl, dated September 14, 1984 1707
  Jean Watkins, dated September 14, 1984 1708
  Kimberly Thompson, dated September 14, 1984 1709
  Jordon Good, dated September 14, 1984 1711
  Hazel Berger, dated September 17, 1984 1712
  Jack Heidelberg, dated September 17, 1984 1713
  Minna Kaye, dated September 17, 1984 1714
  Michael T. Mow, docketed September 19, 1984 1715
  Lawrence Wallin, dated September 19, 1984 1716
  Bettine Wallin, dated September 20, 1984 1717
  M. Holland, dated September 20, 1984 1718
  Kimberley Shotwell, dated September 26, 1984 1719
  James H. Hickman, Jr., external vice president, Associated Students, University of California at Santa Barbara, docketed September 28, 1984 1720
  Donna Lomp, docketed October 4, 1984 1721
  Hon. George E. Brown, Jr., Member of Congress, October 4, 1984 1722
  C. H. Wang, reactor administrator and director, Radiation Center, Oregon State University, October 8, 1984 1724
  Luis M. Barber, dated October 8, 1984 1731
  John M. Bass, docketed October 9, 1984 1732
  Melinda Maxwell-Smith, dated October 10, 1984 1733
  David Seidman, dated October 10, 1984 1734
  Roberta Riley, dated October 10, 1984 1735
  Hon. Henry A. Waxman, Member of Congress, dated October 11, 1984 1736
  Marcia D. Crews, dated October 11, 1984 1737
  Dorothy Garber, dated October 11, 1984 1738
  Ingvard Rasmussen, Deputy Director, Riso National Laboratory, dated October 12, 1984 1739
  Ronald Bakal, Esq., dated October 12, 1984 1742
  Gina L. Pearson, dated October 13, 1984 1745
  Lawrence Miles, dated October 14, 1984 1746
  Sebia Hawkins, Greenpeace U.S.A., dated October 15, 1984 1747
  Thomas Pigford, reactor administrator, University of California, Berkeley, dated October 16, 1984 1748
  Hon. Mel Levine, Member of Congress, dated October 17, 1984 1749
  Otto K. Harling, Director, Nuclear Reactor Laboratory, Massachusetts Institute of Technology, dated October 19, 1984 1750
  Nancy Tamarin, docketed October 19, 1984 1760
  Eula M. McNabb, docketed October 19, 1984 1761
  T. G. Williamson, professor, Department of Nuclear Engineering and Engineering Physics, and R. U. Mulder, director, UVA Nuclear Reactor Facility, University of Virginia, dated October 19, 1984 1762
  Paul E. Gray, president, and Kenneth A. Smith, associate provost and vice president for research, Massachusetts Institute of Technology, dated October 19, 1984 1764
  Anne H. Cahn, director, the Committee for National Security, dated October 22, 1984 1766
  Robert D. Rogge, dated October 22, 1984 1767

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- Robert D. Rogge, dated October 22, 1984—Continued
  - Enclosure: Statement of Richard D. Rogge before the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production regarding the use of weapons-grade uranium fuel in domestic research reactors, October 11, 1984. (See Robert D. Rogge, dated October 11, 1984 in appendix 2 above.)
- Joseph M. Hendrie, president, American Nuclear Society, dated October 22, 1984 1767
- James B. Devine, Deputy Assistant Secretary, Bureau of Oceans and International Environmental and Scientific Affairs, U.S. Department of State, dated October 23, 1984 1771
  - Enclosure: Letter from Richard T. Kennedy, Ambassador at Large, U.S. Department of State, to Nunzio Palladino, chairman, U.S. Nuclear Regulatory Commission, dated January 13, 1984 1773
- A. Francis DiMeglio, director, Rhode Island Atomic Energy Commission, Nuclear Science Center, dated October 23, 1984 1774
  - Enclosure: Memorandum from Kevin Gillis, chair, Social Responsibility Committee, U.C. Student Body President's Council, Associated Students of the University of California, to Student Body Presidents, dated August 23, 1984; Associated Students of the University of California Student Body Presidents' Council resolution supporting the proposed rule by the Nuclear Regulatory Commission on limiting the use of highly enriched uranium in domestic research and test reactors, dated August 18, 1984; sample letter to the Secretary of the Commission; information sheet 1776
- A. Francis DiMeglio, chairman, the National Organization of Test, Research and Training Reactors, dated October 24, 1984 1780
  - Attachment 1: "Analysis of Risks of Diversion of Plutonium or Highly Enriched Uranium," E. L. Zebroski, for presentation at the annual meeting of the Society for Risk Analysis, October 1, 1984. (See attachment to prepared testimony of Edwin L. Zebroski of panel 2 above.)
  - Attachment 2: Letter to the Secretary of the Commission, from P. von de Hardt, head, HFR Division, Joint Research Centre, Commission of the European Communities, dated August 31, 1984, and letter to Dr. Nunzio J. Palladino, chairman, Nuclear Regulatory Commission, from Milt Levenson, president, American Nuclear Society, dated March 19, 1984. (See attachment to prepared testimony of Dr. A. Francis DiMeglio of panel 4 above.)
- Esther Schiller, docketed October 25, 1984 1785
- Sheldon C. Plotkin, cochairperson, Southern California Federation of Scientists, dated October 25, 1984 1786
  - Enclosure: Statement of Dr. Sheldon C. Plotkin before the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production, October 11, 1984. (See Dr. Sheldon C. Plotkin, dated October 11, 1984 in appendix 2 above.)
- Rev. Steven Poteete-Marshall, pastor, the First United Methodist Church of West Los Angeles, dated October 25, 1984 1787
- Paul Leventhal, president, and Daniel Horner, issues director, Nuclear Control Institute, dated October 25, 1984 1788
- James J. McGovern, business manager, Radiochemicals, Union Carbide Corp., dated October 26, 1984 1793
- Don W. Miller, professor and chairman, Nuclear Engineering Program; Walter E. Carey, associate professor, Nuclear Engineering Program, director, Radiation Safety Office; Joseph W. Talnagi, Jr., senior research associate, Nuclear Reactor Laboratory; Brian K. Hajek, associate director, Nuclear Reactor Laboratory; Tunc Aldemir, assistant professor, Nuclear Engineering Program, and Richard D. Myser, associate director, Nuclear Reactor Laboratory, dated October 26, 1984 1798
- Stephanie A. Murphy, nuclear terrorism research project, Adlai E. Stevenson Program on Nuclear Policy, University of California, Santa Cruz, dated October 26, 1984 1803

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Stephanie A. Murphy, nuclear terrorism research project, Adlai E. Stevenson Program on Nuclear Policy, University of California, Santa Cruz, dated October 26, 1984—Continued
    Enclosure: Statement of Stephanie A. Murphy before the Subcommittee on Energy Development and Applications and the Subcommitee on Energy Research and Production, October 12, 1984. (See Stephanie A. Murphy, dated October 12, 1984 in appendix 2 above.)
James C. Warf, professor of chemistry, University of Southern California, dated October 26, 1984 1805
    Enclosure: Statement of Dr. James C. Warf, submitted to the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production, October 12, 1984. (See Dr. James C. Warf, dated October 12, 1984 in appendix 2 above.)
Robert S. Carter, Chief, Reactor Radiation Division, U.S Department of Commerce, National Bureau of Standrds, dated October 26, 1984 1806
Abraham Spindel, dated October 27, 1984 1809
Dan Jaffee, OPIRG codirector, Ohio Public Interest Research Group, dated October 29, 1984 1810
Dick Duffey, dated October 29, 1984 1811
    Attachment: Dick Duffey and Peter F. Wiggins, "University Papers in ANS Transactions, with Enrollments and Degrees," Transactions of American Nuclear Society, vol. 39, p. 53, November 1981 1812
Stuart M. Turnansky, M.D., docketed October 29, 1984 1814
Milan Straka, reactor manager, University of Missouri-Rolla, dated October 29, 1984 1815
N. Tsoulfanidis, chairman and professor; D. Ray Edwards, professor; Albert E. Bolon, associate professor; Arvind Kumar, assistant professor; and Gary Mueller, assistant professor; Nuclear Engineering Department, University of Missouri-Rolla, dated October 29, 1984 1816
Don L. Warner, dean, School of Mines and Metallurgy, University of Missouri-Rolla, dated October 29, 1984 1818
Kevin Gillis, chair, Social Responsibility Committee, U.C. Student Body President's Council, Associated Students of the University of California, dated October 29, 1984 1820
    Enclosure: Letter from Kevin Gillis, to Representative Fuqua, chairman, Subcommittee on Energy and Applications and Representative Lloyd, chairman, Subcommittee on Energy Research and Production, and Statement of Kevin Gillis before the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production, October 10, 1984. (See Kevin Gillis, dated October 10, 1984 in appendix 2 above.)
David Hafemeister, professor of physics, California Polytechnic University, dated October 29, 1984 1822
    Enclosure: Statement of Dr. David W. Hafemeister before the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production regarding the need to convert domestic research reactors from highly enriched to low-enriched uranium fuels, October 10, 1984. (See Dr. David W. Hafemeister, dated October 10, 1984 in appendix 2 above.)
Kristen K. Knox, dated October 29, 1984 1823
Sigrid McLaughlin, Ph.D., Educators for Social Responsibility, University Division, northern California section, dated October 29, 1984 1824
Frances Smith, dated October 30, 1984 1826
William G. Vernetson, acting director of nuclear facilities, Nuclear Facilities Division, University of Florida, dated October 31, 1984 1827
    Attachment: Letter from Robert Q. Marston, president, University of Florida, to Dr. Nunzio J. Palladino, Chairman, U.S. Nuclear Regulatory Commission, dated December 19, 1983 1829
Alvin W. Trivelpiece, Director, Office of Energy Research, U.S. Department of Energy, dated October 31, 1984 1830
Steven Aftergood, executive director, Committee To Bridge The Gap, dated October 31, 1984 1832
    Attachment A: TRIGA 1846
    Attachment B: Advantages of TRIGA fuel for research reactors, October 1981 1849

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  Steven Aftergood, executive director, Committee To Bridge The Gap, dated October 31, 1984—Continued
    Attachment C: TRIGA reactors installations and conversions, February 1980 1856
    Attachment D: Memorandum from Gerald L. Pollack to Commissioner Gilinsky, subject: Converting argonaut reactors at U.S. universities to 4.8 percent LEU fuel, dated February 8, 1984 1858
    Attachment E: Letter from Steven Aftergood, executive director, Committee To Bridge The Gap, to Dr. Enzo Ricci, dated October 29, 1984 1859
    Attachment F: Memorandum from Gerald L. Pollack to Commissioner Gilinsky, subject: Converting reactors at academic institutions from HEU to LEU, dated September 22, 1983 1862
    Attachment G: Statement of Steven Aftergood, executive director, Committee To Bridge The Gap, before the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production on the need to convert domestic and foreign research and test reactors to low-enriched uranium, October 12, 1984. (See Steven Aftergood, dated October 12, 1984 in appendix 2 above.)
  Hon. Alan Cranston, U.S. Senate, dated November 1, 1984 1889
    Attachment: Letter from Senator Alan Cranston to Nunzio J. Palladino, Chairman, U.S. Nuclear Regulatory Commission, dated November 2, 1984 1890
  Donald E. Feltz, director, Nuclear Science Center, and Carl Erdman, professor and head, Department of Nuclear Engineering, Texas A&M University, dated November 1, 1984 1891
  Daniel Hirsch, director, Adlai E. Stevenson Program on Nuclear Policy, University of California, Santa Cruz, dated November 1, 1984 1894
    Enclosure 1: "Weapons-Grade Uranium on Campus: The Need to Convert Research Reactors to Lower Enrichment Fuels," a report to the NRC Commissioners by Daniel Hirsch, January 27, 1984. (See attachment to January 27, 1984, unofficial transcript of the NRC discussion of international implications of conversion of domestic research reactors to LEU use in appendix 4 above.)
    Enclosure 2: "Resolving the Safeguards and Proliferation Risks Associated With Presence of Weapons-Grade Uranium at Research Reactors: Comments on the NRC's Proposed Rule to Convert Research Reactors from Weapons-Grade to Low-Enriched Uranium," by Daniel Hirsch, November 1, 1984 1895
  Sheldon Elliot Steinbach, general counsel, American Council on Education, Division of Government Relations, dated November 1, 1984 1905
  J.P. Hogan, senior counsel, GA Technologies Inc., dated November 2, 1984 1908
    Enclosure 1: Letter from William L. Whittemore, manager, TRIGA Reactors Facility, GA Technologies Inc., to Nunzio J. Palladino, Chairman, U.S. Nuclear Regulatory Commission, dated June 19, 1984 1914
    Enclosure 2: Letter from Harold M. Agnew, president, GA Technologies Inc., to James K. Asselstine, Commissioner, U.S. Nuclear Regulatory Commission, dated June 19, 1984 1918
    Enclosure 3: Letter from Harold M. Agnew, president, GA Technologies Inc., to Frederick M. Bernthal, Commissioner, U.S. Nuclear Regulatory Commission, dated June 19, 1984 1919
    Enclosure 4: Letter from Harold M. Agnew, president, GA Technologies Inc., to Victor Gilinsky, Commissioner, U.S. Nuclear Regulatory Commission, dated June 19, 1984 1920
    Enclosure 5: Letter from Harold M. Agnew, president, GA Technologies Inc., to Thomas M. Roberts, Commissioner, U.S. Nuclear Regulatory Commission, dated June 19, 1984 1921
  R. A. Karam, interim director, Nuclear Research Center, Georgia Institute of Technology, dated November 2, 1984 1926
  E. L. Zebroski, chief nuclear scientist, Electric Power Research Institute, dated November 2, 1984 1927

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  E. L. Zebroski, chief nuclear scientist, Electric Power Research Institute, dated November 2, 1984—Continued
    Attachment 1: Letter from E.L. Zebroski, chief nuclear scientist, Electric Power Research Institute, to Harlan L. Watson, technical consultant, Subcommittee on Energy Development and Applications, dated October 30, 1984. (See Edwin L. Zebroski, questions and answers submitted for the record, dated October 30, 1984 in appendix 1 above.)
    Attachment 2: "Analysis of Risks of Diversion of Plutonium or Highly Enriched Uranium," E.L. Zebroski, presented at the annual meeting of the Society for Risk Analysis, October 1, 1984, Knoxville, TN. (See enclosure to Edwin L. Zebroski, questions and answers submitted for the record, dated October 30, 1984 in appendix 1 above.)
  Michael E. Faden, legislative counsel, Union of Concerned Scientists, dated November 2, 1984 1928
  A.J. Nardi, manager, NES License Administration, Water Reactor Divisions, Westinghouse Electric Corp., dated November 2, 1984 1929
  Hon. Michael D. Barnes, Member of Congress, dated November 2, 1984 1931
  Hon. Richard L. Ottinger and Hon. Edward J. Markey, Members of Congress, dated November 2, 1984 1932
  J.C. McKibben reactor manager, and Don M. Alger, associate director, Research Reactor Facility, University of Missouri, dated November 6, 1984 1933
  David Albright, Federation of American Scientists, dated November 17, 1984 1937
    Attachment 1: Testimony submitted for the record of the September 25 proceedings of the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production on the conversion of domestic civilian research and test reactors to low enriched uranium fuel, by David Albright, Federation of American Scientists, October 15, 1984. (See David Albright, dated October 15, 1984 in appendix 2 above.)
    Attachment 2: "The Amount of Weapon-Grade Uranium Needed to Construct a Nuclear Explosive: Are the Current Physical Protection Requirements Adequate?", by David Albright, Federation of American Scientists, November 17, 1984 draft 1939
  Dr. Charles T. Rombough, chairman, Virginia section, American Nuclear Society, dated November 17, 1984 1946
    Enclosure: Letter from Joseph M. Hendrie, president, American Nuclear Society, to Secretary of the Commission, dated October 22, 1984. (See Joseph M. Hendrie, dated October 22, 1984 above.)

CONVERSION OF RESEARCH AND TEST REACTORS TO LOW-ENRICHED URANIUM [LEU] FUEL

TUESDAY, SEPTEMBER 25, 1984

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS, AND THE SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION,

Washington, DC.

The subcommittees met, pursuant to call, at 1:30 p.m., in room 2325, Rayburn House Office Building, Hon. Marilyn Lloyd (chairman of the Subcommittee on Energy Research and Production) presiding.

Mrs. LLOYD. The Subcommittee on Energy Research and Production will come to order.

Good afternoon, ladies and gentlemen. I do want to apologize for the delay. Just as I started over, we had a vote, and as I started back from the House floor, we had another vote. That is the usual procedure around here.

Before I begin my opening remarks, I ask unanimous consent that we permit our hearings to be recorded by the media and others if they so desire. Without objection, so ordered.

I am hopeful that this hearing will help to clarify whether or not it is necessary to convert our domestic research and test reactors from highly enriched uranium fuel to low-enriched uranium fuel.

We'd like to understand the urgency for the need to convert these reactors to low-enriched fuel. Is the chief basis for conversion to set a nonproliferation example for the rest of the world or are there other important reasons?

I'm skeptical—I am skeptical that any such conversion is warranted as an example which will elicit similar actions on the part of other countries; is needed to address any safeguards or security problems that have been identified; is justified from the standpoint of cost of the conversion or is worth the social costs in the potential loss of these valuable university training tools.

I am hopeful that most universities would accomplish such conversion if ordered to do so, but I am apprehensive that universities might instead be forced to close down their facilities with serious impact on their nuclear engineering departments.

A few years ago, during the previous administration, we were advised that the United States needed to set a nonproliferation example in foregoing certain aspects of nuclear development. Despite the fact that we set an example in arresting nuclear technology development, the rest of the world thumbed their noses at us. Then they proceeded to seek alternative suppliers of all elements of nuclear technology. And I am just wondering if we are headed down this same road of futile example and self-denial. So certainly I hope to hear more about this issue today in our hearings.

If, nevertheless, there are good reasons to order some or all facilities to convert to low-enriched uranium fuel and the Congress and the Nuclear Regulatory Commission conclude that it's necessary to order the conversions, then it is incumbent upon us to identify who should bear the costs of the conversions.

I am hopeful today that we will learn how much it will cost and receive recommendations from witnesses on who should pay for such conversions. We'll also hear today from the Department of Energy who will tell us whether or not the technology exists to convert all of our research and test reactors to low-enriched fuel.

I've been advised that the technology is not completely proven and that much work remains to be done in order to bring it to commercial deployment. I'm also advised that if one could convert all the reactors to low-enriched fuel not all research and test requirements could be met by the utilization of low-enriched uranium fuel.

These facts demonstrate a need to carefully consider exemptions to any rule which would require the conversion to low-enriched fuel. I'm hopeful that the result of this hearing will enable our committee to formulate a reasonable position on future authorizations and appropriations relative to this issue.

I understand that Mr. Fuqua does have an opening statement, as well as Mr. Winn and Mr. Sensenbrenner and Mr. Walker, and without objection, they will be made a part of the record at this point.

[The prepared statements of Mr. Fuqua, Mr. Winn, and Mr. Sensenbrenner follow:]

OPENING STATEMENT

HON. DON FUQUA (D-FLA.)

SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

HEARING ON
CONVERSION OF RESEARCH AND TEST REACTORS
TO LOW-ENRICHED URANIUM (LEU) FUEL
SEPTEMBER 25, 1984

GOOD AFTERNOON, LADIES AND GENTLEMAN. THIS AFTERNOON'S HEARING WILL ADDRESS THE NEED FOR AND POTENTIAL IMPACTS OF REQUIRING UNIVERSITIES, RADIOPHARMACEUTICAL MANUFACTURERS, AND OTHER RESEARCHERS TO CONVERT THEIR RESEARCH AND TEST REACTORS TO LOW-ENRICHED URANIUM FUEL. SUCH CONVERSIONS HAVE BEEN PROPOSED BY THE NUCLEAR REGULATORY COMMISSION TO PROTECT AGAINST POSSIBLE TERRORIST ACTIVITY AND TO SET AN EXAMPLE ENCOURAGING OTHER NATIONS TO COMPLY WITH U.S. NUCLEAR NONPROLIFERATION GOALS.

THE COMMITTEE IS PARTICULARLY CONCERNED ABOUT THE COST IMPACT OF ANY SUCH MANDATED CONVERSIONS ON UNIVERSITIES. IF UNIVERSITIES CHOOSE TO CLOSE THEIR REACTORS RATHER THAN TO BEAR THE COSTS OF CONVERSION, WE COULD SERIOUSLY IMPAIR OUR ABILITY TO TRAIN NUCLEAR ENGINEERS AND SCIENTISTS. WE COULD ALSO DISRUPT IMPORTANT MATERIALS SCIENCES RESEARCH AND RADIOISOTOPE PRODUCTION. WE EXPECT OUR WITNESSES TO SPEAK ON THE NEED, TECHNICAL FEASIBILITY, COSTS, AND BENEFITS OF SUCH CONVERSIONS.

STATEMENT BY THE HONORABLE LARRY WINN, JR.

HEARING ON CONVERSION OF RESEARCH AND TEST REACTORS OF LOW-ENRICHED URANIUM (LEU) FUEL

SEPTEMBER 25, 1984

THANK YOU, MR. CHAIRMAN, FOR THIS OPPORTUNITY TO WELCOME OUR WITNESSES TODAY. THEY INCLUDE REPRESENTATIVES FROM THE U.S. NUCLEAR REGULATORY COMMISSION, THE ELECTRIC POWER RESEARCH INSTITUTE, THREE GOVERNMENT AGENCIES, AND REPRESENTATIVES FROM BOTH INDUSTRY AND UNIVERSITIES. AMONG THESE SEVERAL WITNESSES, WE HAVE REVIEWED A VARIETY OF OPINIONS RELATIVE TO CONVERTED RESEARCH AND TEST REACTORS FROM HIGH-ENRICHED URANIUM TO LOW-ENRICHED URANIUM FUEL.

MR. CHAIRMAN, ALONG WITH ALL THE REST OF US, I SUPPORT THE NON-PROLIFERATION OF NUCLEAR MATERIALS. I CAN CERTAINLY UNDERSTAND THE CONCERN OF THE NUCLEAR REGULATORY COMMISSION THAT HIGH-ENRICHED URANIUM FUELS PROVIDE AN OPPORTUNITY FOR TERRORIST ACTIVITIES. HOWEVER, THROUGHOUT THE TESTIMONY PROVIDED TO US, THERE IS NO MENTION OF THE SAFEGUARDS NECESSARY TO MINIMIZE OR PREVENT THE THEFT OF THESE HIGH-ENRICHED URANIUM FUELS FROM RESEARCH AND TEST REACTORS. IF PRESENT SAFEGUARDS ARE NOT ADEQUATE, THERE MAY BE A POSSIBILITY OF IMPROVING THEM AT A LESSER EXPENSE THAN THAT OF CONVERTING REACTORS TO A LOW-ENRICHED URANIUM FUEL. MAYBE WE CAN GET THAT KIND OF INFORMATION TODAY OR AT A FUTURE DATE FROM THESE WITNESSES.

ANOTHER POINT FOR CONSIDERATION IS THAT THE USE OF LOW-ENRICHED URANIUM FUEL DOES NOT APPEAR TO BE TOTALLY DEFINED AT THIS TIME. ONE WITNESS MENTIONED THE LARGE AMOUNT OF MONEY TO DATE, FAR EXCEEDING EARLY PROJECT ESTIMATES. POSSIBLY WE CAN OBTAIN MORE INFORMATION ON WHAT THE TOTAL COSTS FOR LOW-ENRICHED URANIUM FUEL WILL BE. I CERTAINLY UNDERSTAND THAT WE ARE DISCUSSING A PROPOSED REGULATION BY THE NUCLEAR REGULATORY COMMISSION, RATHER THAN A HARDENED DIRECTIVE. I AM CERTAIN THAT MUCH STUDY AND THOUGHT HAS GONE INTO THIS PROPOSED REGULATION, SO, I LOOK FORWARD TO HEARING OUR WITNESSES.

MR. CHAIRMAN, THIS HEARING SHOULD BE HELPFUL TO US ALL AND I COMMEND YOUR HAVING ORGANIZED IT.

THANK YOU.

OPENING STATEMENT

OF

THE HONORABLE F. JAMES SENSENBRENNER, JR.,

CONVERSION OF UNIVERSITY RESEARCH AND TEST REACTORS TO LOW ENRICHED FUEL

SEPTEMBER 25, 1984

THANK YOU, MR. CHAIRMAN, FOR THIS OPPORTUNITY TO WELCOME OUR DISTINGUISHED WITNESSES TO THIS AFTERNOON'S HEARING ON THE PROPOSED RULE OF THE NUCLEAR REGULATORY COMMISSION REQUIRING THE CONVERSION OF

DOMESTIC RESEARCH AND TEST REACTORS TO LOW ENRICHED URANIUM FUEL.

THE USE OF HIGH ENRICHED URANIUM AS A FUEL IN OUR RESEARCH AND TEST REACTORS REPRESENTS A POTENTIAL OPPORTUNITY FOR THE ILLEGAL DIVERSION OF THE FUEL BY TERRORISTS AND ITS SUBSEQUENT USE IN AN EXPLOSIVE DEVICE. THE NRC HAS PROPOSED A RULE REQUIRING ALL LICENSED RESEARCH AND TEST REACTORS USING HIGH ENRICHED FUEL TO CONVERT TO LOW ENRICHED FUEL. THIS RULE IS PREMISED UPON TWO ASSUMPTIONS: (1) THAT ANY REDUCTION IN THE POTENTIAL ACCESS TO THESE SUPPLIES WILL CONSTITUTE A REDUCTION IN THE PROLIFERATION RISK; AND (2) THAT THE EXAMPLE SET BY THE U.S. WOULD EVOKE A SIMILIAR RESPONSE FROM OTHER NATIONS. I LOOK FORWARD TO THE WITNESSES THOUGHTS ON THE VALIDITY OF THEE ASSUMPTIONS.

MOREOVER, THE EFFECT OF THIS PROPOSED RULE UPON THE LICENSEE, AND ITS IMPLICATIONS FOR RESEARCH IN THIS COUNTRY, PARTICULARY IN LIGHT OF THE BUDGETARY IMPACTS OF THE CONVERSION, MUST BE ADDRESSED SATISFACTORILY PRIOR TO THE IMPLEMENTATION OF THE RULE. I LOOK FORWARD TO YOUR THOUGHTS ON THE EFFECT OF THE RULE UPON LICENSEES AND HOW, IF SOUGHT TO BE IMPLEMENTED, ITS IMPACT CAN BE MINIMIZED.

THANK YOU, MR. CHAIRMAN.

Mrs. **Lloyd.** We also have written testimony from the Nuclear Control Institute, Babcock & Wilcox Co., the GA Technologies, Inc.—without objection, will be inserted in the appendix to the record.

Since we have many witnesses today and limited hearing time—we will have, I anticipate, many votes today—we've asked our witnesses to limit their oral presentation to 10 minutes or less. I do ask for your cooperation in meeting this schedule and thank you in advance for your cooperation.

Before I introduce the first witness, I intended to ask our ranking Republican members if there are other statements they would like to make, but since they are not here, then we will proceed to our witnesses.

Our first witness today is certainly a good friend of mine, the Honorable Frederick Bernthal, who is Acting Chairman of the U.S. Nuclear Regulatory Commission and he is also accompanied by the Honorable James Asselstine, a Commissioner at the Nuclear Regulatory Commission. Certainly both of these gentlemen—we're happy to see you today and they're familiar faces on Capitol Hill and we do welcome you to appear before our committee.

I understand, Dr. Bernthal, that you'll be presenting testimony for the Commission and both of you will be available for questioning. Your entire statement will be made a part of the record and you may summarize, Fred, but please proceed as you wish.

STATEMENT OF DR. FREDERICK BERNTHAL, ACTING CHAIRMAN, U.S. NUCLEAR REGULATORY COMMISSION; ACCOMPANIED BY JAMES ASSELSTINE, COMMISSIONER, U.S. NUCLEAR REGULATORY COMMISSION

Dr. **Bernthal.** Thank you, Madam Chairman.

I would say it's a pleasure to be back in this room. I've spent many hours here listening many times before——

Mrs. **Lloyd.** I think that it's your first time to be at the witness desk.

Dr. **Bernthal.** I believe that's——

Mrs. **Lloyd.** How's it feel to be over there?

Dr. **Bernthal.** It was easier listening, I think, than it was to be heard.

Mrs. **Lloyd.** Maybe we'll see what you learned today, Fred.

Dr. **Bernthal.** That's what I'm afraid of. [Laughter.]

Mrs. **Lloyd.** We have the utmost confidence in both of you.

Dr. **Bernthal.** Let me begin by saying that I have tried to abbreviate my statement somewhat, but certainly the statement is available for the public and the statement represents the opinion of the Commission.

Commissioner Asselstine, I believe, may have some comments in addition.

My name is Fred Bernthal. I am a Commissioner at the NRC. Chairman Palladino and Commissioners Roberts and Zech regret that they had previous commitments today that preclude them from attending.

I am pleased to appear before you in response to your request, Madam Chairman, to testify concerning the conversion of domestic research and test reactors to low-enriched uranium fuel. As you know, the Commission is considering amending its regulations to limit the use of highly enriched fuel, which I'll be calling HEU from now on, in domestic and research test reactors.

The proposed rule has been published in the Federal Register to obtain public comment at this point. For the purpose of this proceeding today, I should say that we define highly enriched uranium as fuel in which the weight percent of the Uranium-235 isotope in the fuel is 20 percent or greater. The significance of this type of fuel, as you all know, is that in appropriate form and quantity, it can in principle be employed to construct a nuclear explosive device.

The proposed rule is a consequence of a number of events that have occurred in the last several decades. I would like to spend a few minutes recounting those events so we understand how we got to where we are today.

Originally, only LEU fuel was meant to be exported for use in research reactors. In the late 1960's, HEU became available and, in fact, became the fuel of choice in order to meet certain specific experimental needs.

In the 1970's, certain events heightened concern about nuclear proliferation, and U.S. nuclear export policy turned toward encouraging the reduction of U.S.-supplied HEU inventories for fueling research and test reactors abroad. And it was against this background that the Reduced Enrichment Research and Test Reactor [RERTR], program was established in 1978 by the Department of Energy.

In August 1982, the Commission issued a policy statement relating to its licensing responsibilities for the export of special nuclear material, including high-enriched uranium. The present proposal of the Commission represents a step in that direction. Needless to say, one can never be certain that actions taken by us domestically will have the desired positive influence abroad, but the Commission continues to believe that the policy contained in the proposed rule is sound.

Another reason for considering this proposal is that as long as high-enriched uranium exists at nonpower reactors, some residual risk of malevolent use, or misguided attempt at such use exists.

Our pursuit of security improvements at nonpower reactor facilities over the last several years has been an attempt to balance costs and risks. Currently available information contains no indication of a specific threat aimed at a domestic facility. However, as we all know, acts by international terrorists have repeatedly shown that a threat can materialize without sufficient warning from intelligence sources. Therefore, it may be prudent for the NRC to consider additional domestic security measures to increase protection of the HEU materials still under NRC license.

As to the potential impact of the proposed rule on operators of research and test reactors, let me address that issue in two parts. For those seeking a construction permit for a reactor requiring HEU fuel, the proposed rule would now require that applicants demonstrate that the reactor would have a unique purpose, and unique purpose is simply defined as a project or program which cannot reasonably be accomplished without the use of HEU fuel in the reactor.

Now, as you can see, the rule does not prohibit the use of HEU fuel in new reactors, but it is intended to permit only those activities which are well-justified, and practically speaking, we do not see this aspect of the proposed rule affecting researchers since we don't anticipate any construction permit applications for nonpower reactors at this time.

The other part of the proposed rule would have a greater impact on licensees, or could have a greater impact. For existing reactors, unless the licensee can meet the unique purpose test, the proposed rule would prohibit the licensee from acquiring additional HEU fuel if LEU fuel is available and if such fuel meets the Commission's health and safety criteria.

In addition, the licensee would be required to replace all HEU fuel in his possession with available LEU fuel in accordance with the schedule based on availability of replacement fuel and consideration of other factors. The process we envision for accomplishing conversion of existing reactors is that if the replacement of HEU fuel with LEU does not change the technical specifications incorporated in the license or involve an unreviewed safety question as defined in our regulations, the licensee may then replace HEU with LEU without amendment to the license.

Obviously, if there are changes to the technical specifications, that conversion would require the usual careful safety reviews.

Now, the comments we have received indicate that academic institutions, which operate most of the research reactors in this country, are particularly concerned about the cost of conversion. They're on tight budgets and they maintain that they cannot afford to pay the costs of conversion. They're concerned about the cost of the new LEU fuel, as well as the cost of removing, transporting and reprocessing their present HEU cores.

They're also concerned that it would be expensive and time-consuming to meet NRC requirements for relicensing their reactors once they become subject to conversion, especially if that relicensing process were subject to public hearings.

The Commission, Madam Chairman, intends to consider carefully public comments on its proposed rule, to proceed judiciously toward adopting whatever final rule is appropriate, and to implement any final rule in a careful manner. We believe that requiring research reactors to use LEU fuel is desirable, provided that DOE funding for replacement fuel for current licensees is made available and our assumptions regarding the administration and licensing cost of conversion are correct.

I think that I should say that applies to all research reactors that we're talking about here, not just new research reactors. I think that's a typo in my prepared statement here.

Should the Commission decide to proceed with conversion, we will attempt to apply a generic licensing approach to conversion in order to minimize or eliminate licensee administrative costs and avoid disruption of ongoing research and educational programs. If the RERTR program succeeds in obtaining its goals over the next few years, the likelihood of applying a generic approach for most reactors will no doubt increase and thus help reduce costs and minimize the procedural steps that would be required to achieve conversion.

And finally, I would just close my prepared remarks by saying that only if the Federal Government, through the Department of Energy, continues to develop advanced fuel types and to fund fully the replacement of fuel will this program be able to succeed and progress.

We continue to believe that such conversion is a worthwhile and significant long-term objective for all nonpower reactor facilities. Continued support by the Congress of DOE's RERTR and university fuel assistance programs is essential, therefore, to achieving the goal of reducing HEU inventories at NRC-licensed facilities.

Thank you and I think we'd be happy to take any questions that you might have.

[The prepared statement of Dr. Bernthal follows:]

TESTIMONY OF COMMISSIONER FREDERICK M. BERNTHAL
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
AND THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT
AND APPLICATIONS
OF THE
HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY
SEPTEMBER 25, 1984

My name is Frederick Bernthal. I am a Commissioner of the Nuclear Regulatory Commission. With me today is Commissioner Asselstine. Chairman Palladino and Commissioners Roberts and Zech regret that previous commitments preclude them from attending. I am pleased to appear before you in response to your request to testify concerning the conversion of domestic research and test reactors to low enriched uranium (LEU) fuel.

As you know, the Commission is considering amending its regulations to limit the use of highly enriched uranium (HEU) in domestic research and test reactors. The proposed rule has been published in the Federal Register to obtain public comments. For the purpose of this proceeding, we define highly enriched uranium as fuel in which the weight percent of the U-235 isotope in the uranium fuel is 20 percent or greater. The significance of this type of fuel is that, in appropriate form and quantity, it can in principle be employed to construct a nuclear explosive device. While there is no firm dividing line between uranium enrichments that can be utilized in an explosive device and enrichments that cannot, 20 percent has been considered a reasonable dividing line between low enriched uranium and high enriched uranium. The rule would require reactor operators to use fuel that is less than 20 percent, or to come as close to that line as possible. It also reflects the fact that technological advances in fuels are making it possible to produce lower enrichment fuels for many reactors without significant reduction in performance.

The proposed rule is a consequence of a number of events that have occurred in the last several decades. Originally, only LEU fuel was meant to be exported for use in research reactors. In the late 1960's HEU became available and the fuel of choice in order to meet specific experimental needs. In the 1970's certain events heightened concern about nuclear proliferation, and U. S. nuclear export policy turned toward encouraging the reduction of U. S. supplied HEU inventories for fueling research and test reactors abroad. Against this background the Reduced Enrichment Research and Test Reactor (RERTR) program was established in 1978 by the Department of Energy.

In August, 1982, the Commission issued a policy statement related to its licensing responsibilities for the export of special nuclear material, including high enriched uranium. In this statement the Commission noted that the widespread use of HEU fuel, which at that time involved a large number of domestic and international fuel shipments, increases the risks of proliferation through theft and diversion, and therefore efforts should be made to reduce HEU inventories. The assumption was that any reduction in the potential for access to these inventories would constitute a reduction in the proliferation risk. Based on the progress of the RERTR program, and as part of the policy to strongly encourage conversion by foreign operators, the Commission promised to take steps to encourage similar action by U. S. research reactor operators. The present proposal represents a step in that direction. Needless to say, one can never be certain that actions taken by us domestically will have the desired positive influence abroad, but the Commission continues to believe that the policy contained in the proposed rule is sound.

Another reason for considering this proposal is that as long as high enriched uranium exists at non-power reactors, some residual risk of malevolent use, or misguided attempt at such use, exists. Our pursuit of security improvements at non-power reactor facilities over the last several years has attempted to balance costs and risks. Currently available information contains no indication of a specific threat aimed at a domestic facility. However, acts by international terrorists have repeatedly shown that a threat can materialize without sufficient warning from intelligence sources. Therefore, it may be prudent to consider additional domestic security measures to increase protection of the HEU material still under NRC license. So, in conjunction with our consideration of the conversion issue, we are also considering increased security measures at non-power reactors. For example, the Commission has been considering for the past several months a proposal which would require all fresh HEU fuel to be removed from those few sites which still have some small quantities stored on-site, and would tighten the accountability procedures for maintaining the required 100 rad/hour deterrence level of all stored fuel, as required by NRC regulations.

As to the potential impact of the proposed rule on operators of research and test reactors, let me address the issue in two parts. For those seeking a construction permit for a reactor requiring HEU fuel, the proposed rule would require that applicants demonstrate that the reactor would have a "unique purpose". Unique purpose is defined as a project or program which cannot reasonably be accomplished without the use of HEU fuel in the reactor.

As you can see, the rule does not prohibit the use of HEU fuel in new reactors, but is intended to permit only those activities which are well justified. Practically speaking, we do not see this aspect of the proposed rule affecting researchers since we do not anticipate any construction permit applications for non-power reactors at this time. Should there be any, we believe there is sufficient flexibility in the proposed rule to permit legitimate research using HEU fuel.

The other part of the proposed rule could have a greater impact on licensees. For existing reactors, unless the licensee can meet the "unique purpose" test, the proposed rule would prohibit the licensee from acquiring additional HEU fuel if LEU fuel is available and such fuel meets the Commission's health and safety criteria. In addition, the licensee would be required to replace all HEU fuel in his possession with available LEU fuel, in accordance with a schedule based on availability of replacement fuel and consideration of other factors. These other factors include the availability of shipping casks, reactor usage, and financial support. A final schedule would be established by discussion with our licensing staff.

The process we envision for accomplishing conversion of existing reactors is that if the replacement of HEU fuel with LEU fuel does not change the technical specifications incorporated in the license or involve an unreviewed safety question as defined in our regulations, the licensee may replace HEU with LEU fuel without amendment to the license. Obviously, if there are changes to the technical specifications, the conversion would require the usual careful safety reviews. Information available to date indicates that conversion of a number of non-power reactors from HEU to LEU fuel is technically feasible, and if the goals of the RERTR program are successfully achieved over the next five years, conversion will be technically feasible for nearly all the remaining reactors.

Comments we have received indicate that academic institutions which operate most of the research reactors are particularly concerned about the cost of conversion. They are on tight budgets and maintain that they cannot afford to pay the costs of conversion. They are concerned about the cost of the new LEU fuel as well as the costs of removing, transporting, and reprocessing their present HEU cores. They are also concerned that it would be expensive and time consuming to meet NRC requirements for relicensing the reactors once they become subject to conversion, especially if the relicensing process were subject to public hearings.

The Commission intends to consider carefully public comments on its proposed rule, to proceed judiciously toward adopting whatever final rule is appropriate, and to implement any final rule in a careful manner. We believe that requiring new research reactors to use LEU fuel is desirable, provided that DOE funding for replacement fuel for current licensees is made available and our assumptions regarding the administration and licensing costs of conversion are correct. Should we decide to proceed with conversion, we will attempt to apply a generic licensing approach to conversion in order to minimize or eliminate licensee administrative costs and avoid disruption of ongoing research and educational programs. If the RERTR program succeeds in attaining its goals over the next few years, the likelihood of applying a generic approach for most reactors will no doubt increase and thus help reduce costs, and minimize the procedural steps that would be required to achieve conversion.

Only if the Federal Government, through the Department of Energy, continues to develop advanced fuel types and to fund fully the replacement of fuel will this program be able to progress. We continue to believe that such conversion is a worthwhile and significant long-term objective for all non-power reactor facilities. Continued support by the Congress of DOE's RERTR and university fuel assistance programs is essential, therefore, to achieving the goal of reducing HEU inventories at NRC-licensed facilities.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
Office of Public Affairs
Washington, D.C. 20555

BIOGRAPHY

FREDERICK M. BERNTHAL

Frederick M. Bernthal, who served on the faculty at Michigan State University and later on the legislative staff of Senator Howard Baker, was sworn in as a member of the Nuclear Regulatory Commission on August 4, 1983.

Prior to his nomination by President Reagan and confirmation by the Senate, Mr. Bernthal was chief legislative assistant to Senator Baker of Tennessee since 1980. He also served as legislative assistant from 1978-1979.

Previously, Mr. Bernthal was a professor of chemistry and physics from 1970-1977 at Michigan State and taught a number of classes designed to introduce students to the understanding and safe handling of radioactivity. For five years, he was a member of the University Reactor Safety Committee and the University Radioisotopes Committee.

During the last 15 years, Mr. Bernthal has engaged in collaborative research with nuclear scientists from Denmark, Germany, Canada and the United Kingdom. He has done advanced study at Yale University, and was a visiting scientist at the Niels Bohr Institute, University of Copenhagen, in 1976-1977.

A member of the American Physical Society and the American Chemical Society, Mr. Bernthal is the author of more than 40 scientific publications in professional scientific journals.

He was graduated with a bachelor of science degree from Valparaiso (Indiana) University in 1964 and received his PhD. in nuclear chemistry from the University of California at Berkeley in 1969.

Mr. Bernthal was born January 10, 1943. He is a resident of Oak Ridge, Tennessee, and is currently living in Washington, D.C.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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Washington, D.C. 20555

BIOGRAPHY

JAMES KILBURN ASSELSTINE

James Kilburn Asselstine was sworn in as a member of the Nuclear Regulatory Commission on May 13, 1982 to serve a term ending June 30, 1987.

Before his nomination by President Reagan and confirmation by the U.S. Senate, Mr. Asselstine served as Associate Counsel of the Senate Committee on Environment and Public Works since January 1981. Previously, he was Minority Counsel for that committee's Subcommittee on Nuclear Regulation from 1978 to 1981. He also had served as Assistant Counsel for the former Congressional Joint Committee on Atomic Energy from 1975 to 1977.

From 1977 to 1978, Mr. Asselstine was a staff attorney in the Regulations Division of the NRC's Office of Executive Legal Director, and from 1973 to 1975 was a legal intern and staff attorney for the NRC's Atomic Safety and Licensing Appeal Panel.

He was graduated from Virginia Polytechnic Institute in 1970 with a bachelor of arts degree, and received his law degree from the University of Virginia in 1973.

Mr. Asselstine was born June 7, 1948. He and his wife live in Alexandria, Virginia.

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June 1982

Mrs. **Lloyd**. Thank you very much.

The question that I ask is for either of you to address the issues. In your prepared statement, Fred, you indicated that there might be a potential proliferation concerning traffic of the highly enriched uranium. Now, I can understand that on international shipments, but are you suggesting that we should worry about this in our domestic shipping, the diversion——

Dr. **Bernthal**. Well, there is reason for some concern, I think, as long as fresh, highly enriched uranium fuel exists on-site or is being domestically shipped in kilogram quantities. You always have the possibility of diversion. I might emphasize that the statement, I think, did not express so much a concern over the transportation itself. In my judgment, at least, the greatest risk would be for a misguided effort itself, perhaps, rather than an actual successful diversion and attempt to fabricate a weapon. Misguided effort itself, directed at the facilities, may be the paramount realistic concern here.

Mrs. **Lloyd**. Why would the Government want to divert this material for weapons? It seems rather incredible why they would choose this for diversion.

Dr. **Bernthal**. If you're asking why a terrorist group, for example, might choose to try and divert this material, well, it's not the—it's not perhaps the easiest target, but it is a target. The fact is that we're still talking about kilogram quantities of highly enriched uranium that are being shipped to supply a number of research reactors in this country and, although it may not be the easiest path in the world to fabrication of an actual device, at the very least, the possibility for blackmail exists and I would think that it would be in the interest of everyone concerned if we would address that problem and try to eliminate it.

Mrs. **Lloyd**. Well, you're speaking of terrorists, diversion by terrorists?

Dr. **Bernthal**. That's right.

Mrs. **Lloyd**. Well, aren't these shipments pretty made—pretty much made in supersafe vehicles that are classified?

Dr. **Bernthal**. Well, yes, they are if they are greater than 5-kilogram quantities. If they are category 1 quantities, then, of course, there are extensive safeguards, procedures, that are applied to such shipments.

In the case of the more common shipments of much smaller quantities of material, the—the precautions that are taken are—are less extensive, but I would say that this—this whole problem, Madam Chairman, has perhaps suffered from too much publicity, and that in itself has become a concern to me, at least, and a case of what I consider closing a rather important loophole here, as opposed to—as you point out, perhaps the major or the favorite target that might appear for terrorist activity.

Mr. **Asselstine**. Mrs. Lloyd, I would just add that I think—I agree with the points that Commissioner Bernthal has made. I think that the concern we have is that by having these shipments of high-enriched uranium or having supplies of high-enriched uranium at university reactors, for example, you make the shipments and those types of reactors more tempting targets, more inviting targets for potential acts of sabotage or theft or diversion than they would otherwise be with low-enriched uranium. I think that is one of the benefits that we see from conversion. You reduce the potential threat or potential risk to—to those shipments and to those types of facilities.

Mrs. LLOYD. The universities that I have heard from are really afraid of costly relicensing processes. I'm sure you're—well, that there is organized opposition to this in the regulatory process.

Do you, as Commissioners, feel that they have reason for their concern?

Dr. BERNTHAL. I cannot sit here and tell you, Madam Chairman, on my own behalf, in any case, that there is no reason for concern because we—we have recently witnessed an event at the UCLA reactor that is entirely unrelated, I should say, to any action that the Commission contemplates in respect to the HEU/LEU problem. In that case, as you know, litigation in what normally would be a routine relicensing procedure managed to extend those procedures for up to 4 years, I believe, to the point where the university finally threw in the towel and shut down the reactor.

In any case, it was unrelated to the issue that we're considering here today. I've consulted with our general counsel and I understand that at least there is counsel from the executive legal director's staff here today and you might wish to hear them comment. I have been unable to get absolute assurances—if that's ever possible from lawyers——

Mrs. LLOYD. Well, you——

Dr. BERNTHAL [continuing]. On litigation.

Mrs. LLOYD [continuing]. You said that there would be a caveat in your regulation that you would not ask them to convert if their projects could be—could not be accomplished without highly enriched fuel. OK.

Could you also consider another provision if they would, in fact, have to turn in the towel on some of their worthwhile projects?

Mr. ASSELSTINE. We flagged that item as one that we did want comment from the universities on in particular. We've also identified that as a concern that we know they have and that we want to make sure that we address.

We said in our proposed statement of consideration on the proposed rule that we believed if the RERTR Program moves forward as we expect it to, that in most, if not all instances, the—the approvals would not require a hearing or triggering opportunity for a hearing that would be caused by changes in the technical specifications for the plant or an unreviewed safety question. That's an item that I think we'll want to continue to look at as we see the comments, but our objective is to try and arrange for a generic review and approval of any licensing changes so that we would minimize or eliminate the possibility of the kinds of costly and lengthy hearings that I think the universities are concerned about.

I would just add that in the case of the reactor that has converted, the University of Michigan reactor, it was possible to—to convert that reactor fairly easily from a technical standpoint, and as far as I am aware, there were not licensing, serious licensing problems associated with that review.

That doesn't mean that won't be the case—that it won't be the case for all other reactors, but at least the experience that we have so far is positive.

Mrs. LLOYD. I'm running out of time, I realize this. Let me ask one final question. Does any single reactor have a sufficient quantity of HEU fuel to make a nuclear explosive device? To your knowledge?

Dr. BERNTHAL. I have to answer that in two parts. First of all, if you ask whether enough HEU exists, including the irradiated fuel that might be in the reactor in storage, the answer would be, yes, there are a number that in principle, and I should emphasize "in principle," could—that have sufficient inventory for fabrication of a weapon.

Now, if the question is whether any reactors currently store unirradiated fuel in sufficient quantities for that purpose, the answer is no. That simply isn't the case. There are a number of reactors, however, that do have a sufficient quantity of irradiated fuel, whatever difficulties that might involve in fabrication of a weapon.

Mrs. LLOYD. I realize I'm not going to get to ask all my questions. I would ask all the witnesses if you would consent to questions in writing that we will also put into the record.

Dr. BERNTHAL. Be happy to.

Mrs. LLOYD. Thank you very much.

Mr. Chandler.

Mr. CHANDLER. Thank you, Madam Chairman.

I'd like to followup on that question that you raised, which I think is an important one to this committee. As I understand your response, you feel that there would be, in principle, enough of this material—at least some of the sites, one site, that a weapon could be produced, but realistically, how many—if a terrorist were going to break into these places, how many of them are they going to have to break into to get enough of the fuel to make a weapon?

Dr. BERNTHAL. Well, if the question is—there are no clearcut answers here, but if the question is how many would they have to break into to collect enough fresh unirradiated fuel as things currently stand and perhaps we can put into that category certain other facilities that are very, very low power and, therefore, have a relatively low irradiated fuel radiation level, if I can use that terminology, it would require the simultaneous invasion of—I would guess, at least two of those facilities to have a shot and realistically probably several of those facilities. It is not a simple question, but three or four is a realistic estimate, I think.

Mr. ASSELSTINE. I think two in some instances. You'd have to know which two. One of the things I'd add, Mr. Chandler, that we are concerned about is the amount of fresh fuel that is stored at some of these reactors and both Fred and I have advocated taking a look at possibly moving some of that fresh fuel out of those facilities back to the Department of Energy where it could be more easily and safely guarded and protected, rather than having this fresh fuel out there dispersed among the reactor sites where it might be more vulnerable.

Mr. CHANDLER. And that raises a question that I was going to ask and that's concerning your look in the development of this rule—did you look at the security measures that are provided at these various institutions? Also, the chairperson raised the question of shipments and security for those shipments and there are, obviously, as you point out, two distinct types of security, depending on the amount involved and did you consider changes in—in the shipment procedures?

Dr. BERNTHAL. Yes. The Commission, in fact, has before it now a paper which it has been considering for some several weeks at least which might involve tightening up the procedures for shipment, as well as the security procedures onsite at all nonpower reactor sites.

Now, was the other part of the question whether my judgment is that there is a current——

Mr. CHANDLER. Your analysis of the—of the security that's provided and your assessment of whether it's adequate. Who does provide the security, by the way?

Mr. ASSELSTINE. The university.

Dr. BERNTHAL. The universities themselves.

Mr. CHANDLER. Their—whatever police force they have.

Dr. BERNTHAL. That's right. And, in fact, I can comment that—from personal experience, I do not detect that there is a major problem of security, but that's not to say that there is not a credible possiblity and I think that's essentially what we're trying to do here, is deal with that.

We might ask if one of our people from NMSS is here. He might like to add to that comment on exactly what the security situation is in their judgment on these sites.

Mr. ASSELSTINE. Let me add a couple of points if I could, also, Mr. Chandler. I think that this is an area where there is a benefit from this rule for the longer term. For myself, I suspect that if high-enriched uranium continues to be stored at the research reactors for a longer period of time, and particularly if there's a problem at one of the research reactors, you're likely to see increased physical security requirements, including trying to prevent material from being removed from the reactors, trying to prevent an insider's involvement in a theft or diversion or sabotage, enhanced or increased law enforcement response.

There are some areas where at universities we don't have the same kinds of physical protection requirements that we—that we do in some other areas. And there are areas where improvements could be made.

I think that it's important to recognize when you look at cost, that those things are going to cost money and they're going to cost the universities money. Over the long term, it may be more expensive, particularly if there's a problem at one of these facilities, to meet those kinds of enhanced physical protection and physical security requirements than going to conversion.

I also think if you have a serious problem at one of these universities, you may well end up losing a lot of the technical capability that you now have because universities may well decide that those kinds of physical security arrangements are incompatible with the educational purposes of the institution or just that the reactor is more trouble than—than it's worth.

I think that is an area where there's a benefit from the conversion program that people may have not recognized.

Mr. CHANDLER. Have you assessed the cost of conversion and the cost of upgraded security, considered whatever loss of efficacy with the conversion is involved and compared the two so that you are comfortable that conversion is by far the better way to go in terms of cost——

Dr. BERNTHAL. Well——

Mr. CHANDLER [continuing]. And efficacy?

Dr. BERNTHAL. Yeah. It's not—they're not entirely comparable. One can always argue that increased security and some of those measures would be quite inexpensive. I should add that certain of the increased security precautions need not be terribly expensive at all. Nevertheless, depending on the degree of assurance that one requires, you could never say with certainty, as you could in the case of conversion, that the—the threat has essentially disappeared.

I think that is the principal argument for spending the $12 million, as I understand the best estimate to be, in going ahead in some sensible, reasonable fashion with the conversion process. That—you simply remove the threat entirely, unquestionably and finally——

Mr. CHANDLER. Does the Commission——

Dr. BERNTHAL [continuing]. If you proceed with conversion.

Mr. CHANDLER. Does the Commission have the authority, if the decision were made to require enhanced security measures, do you have the authority to require the universities to provide that?

Mr. ASSELSTINE. Yes.

Dr. BERNTHAL. Yes, we certainly do.

Mr. CHANDLER. And inspection and——

Mr. ASSELSTINE. Yes.

Dr. BERNTHAL. Yes, sir.

Mr. CHANDLER. Are there standards now that you impose that they must meet and——

Mr. ASSELSTINE. Yes, there are.

Dr. BERNTHAL. For both types of facilities. Both those with the so-called category 1 quantities and category 2.

Mr. CHANDLER. Thank you, Madam Chairman.

Mrs. LLOYD. Thank you very much, Mr. Chandler.

Mrs. Schneider.

Mrs. SCHNEIDER. I'd like to elaborate further on the cost questions, but first, Mr. Bernthal, I'd like to commend you for taking action, which we don't often see in the halls of Congress, and that is what I would characterize as progressive. You are looking at a potential problem and taking action to prevent such a crisis from occurring. I think it is certainly to be commended, whereas all to often, we react, rather than plan for the future and so I commend you on looking at this particular problem and I assume that in your looking, you had done extensive cost-benefit analyses.

Dr. BERNTHAL. Well——

Mrs. SCHNEIDER. Is that correct?

Dr. BERNTHAL [continuing]. It's hard to do a complete cost-benefit analysis. First of all, I think, when you're dealing with—as we are in this case, with a terrorist threat—that is never an easy process to assess, cost benefit, when you're trying to predict the unpredictable, that is, the activities of human beings.

The Commission, I would say at this point, has not solidified, for example, its recommendations on what increased security requirements it might recommend imposing, so at this point, I would not say that there has been a thorough cost benefit analysis done.

Mr. ASSELSTINE. I think we can do fairly well in trying to identify what the costs of conversion are going to be——

Mrs. SCHNEIDER. Uh-huh.

Mr. ASSELSTINE [continuing]. We have our estimates of those. I know——

Mrs. SCHNEIDER. And those are?

Mr. ASSELSTINE. About $12 million for all of the university reactors that we think could convert. There are some that we don't believe can convert.

Mrs. SCHNEIDER. And those nonuniversity reactors, for example, like Union Carbide and others, the costs would be left up to the private sector for conversion purposes.

Dr. BERNTHAL. Presumably, yes.

Mr. ASSELSTINE. Unless——

Dr. BERNTHAL. That is certainly up to the Congress.

Mr. ASSELSTINE. Unless those facilities can show that they serve a unique purpose and that that purpose cannot be provided with low-enriched uranium. If they can establish that, then they don't have to convert at all.

Mrs. SCHNEIDER. And who would make that judgment? Would it be the NRC?

Dr. BERNTHAL. The Commission would make the judgment, yes.

Mrs. SCHNEIDER. You are aware that we've already earmarked $1.25 million in our 1985 DOE budget for conversion purposes. And you're estimating about $12 million.

Dr. BERNTHAL. That's right.

Mrs. SCHNEIDER. To what degree might it be possible to take some of the funding that is already floating around in the NRC and divert some from some of the current programs to this conversion program?

Dr. BERNTHAL. I don't think that you'll get much difference of opinion among the members of the Commission on—on that issue, Mrs. Schneider. I've—my understanding is that we are facing a period in the next 18 months to 2 years here of being asked to license a large number of power reactors. We've already had our budget cut $40 million and the research program itself——[1]

Mrs. SCHNEIDER. That is $40 million as an overall percentage of what?

Dr. BERNTHAL. It's roughly a little less than 10 percent, I guess.

Mrs. SCHNEIDER. Well, you're doing better than some other DOE programs, to say the least.

Dr. BERNTHAL. Well, we have some extraordinary requirements ahead of us, and unfortunately, I should say that because we have so little flexibility, those cuts have largely had to come out of the very area that in principle, whether or not the practice would be a good idea—that is, out of the research programs that might conceivably be used to fund this conversion.

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[1] See appendix II P.—.

I'm not necessarily recommending that course. I think it's more appropriate for DOE to do that funding.

Mr. Asselstine. Mrs. Schneider, if I could add to that. Most of the—of the costs that we see for the conversion really falls in the replacement fuels cost. That is a program that the Department of Energy has traditionally run. We also recognize that conversion is not something that can happen immediately. We see the reactors—the university research reactors—falling into three categories. We think there is one category where the technology already exists to do the conversion and those could probably go ahead. That's a fairly small number of reactors, I think three or four in addition to the University of Michigan reactor that's already converted.

Then there's the second category of two reactors, MIT and University of Missouri, that we think the technology isn't there and it's unlikely that the technology will be there to convert. And those two probably will not be able to convert and still carry out their purposes.

The third category is most of the reactors, and that's an area where the DOE's program for developing the new fuel is going ahead. We have every reason to believe that the new fuel will be developed, but it's going to take a little time to develop it. What we really need is continued full funding of the RERTR program to make sure that that fuel is developed as soon as possible and then funding for the Department of Energy to provide the replacement fuel for those reactors as soon as it's proven to be technically feasible.

Mrs. Schneider. Well, let me say that in the public interest, it appears that your goal is lauditory, but my concern—and I assume that it ought to be your concern—that we have a considerable national deficit that we're looking at and it is imperative upon both you and me, and us up here, to look at decisions that will, number one, serve the public interest, but will also be cost effective and how we go from point A to point B, I think we're looking at some guidance from all of you, especially in terms of funding.

So I think that we'll have to leave that question open and I'm still receptive to any recommendations.

I'd like to ask one more technical question. I'm interested to know whether all the domestic research and the different test reactors can convert to the—to the lower level of fuel and still accomplish all of the research goals that they have established and the reason that I raise this question is because one of my constituents, who will have the opportunity to testify in a short while, says the following:

> At an immediate power level reactor, the 10 percent reduction in available neutron flux caused by conversion is significant. Recently the neutron spectroscopy group in the URI Physics Department spent 2 years designing and building new beam port plugs which are expected to increase the neutron flux in their experimental setup by 10 percent. Conversion wipes out—wipes this out completely.

Now, how critical is that—the fact that this would be completely wiped out? What impact is there on the national interests insofar as continuation of research in this area is concerned?

Dr. Bernthal. Let me just say, first of all, that I think DOE could better answer that question. I have to observe that I've done some of these experiments in my earlier, perhaps more legitimate, life [laughter] and the fact of the matter is that most of these experiments—and that's not to minimize the argument that's being made here—when they are counting experiments, a 10-percent change in the rate at which you get counts is generally not a totally destructive situation unless you're really operating on the borderline in the experiment.

On the other hand, in some cases, the neutron spectrum itself, that is, the various velocities that the neutrons might have as they emerge from the reactor, has been very, very well calibrated at great length and that can cost a research program a good deal of time and things like that, we're just going to have to look at rather carefully.

Mrs. SCHNEIDER. Thank you very kindly. Obviously we'll have the opportunity for rebuttal later on and I assume my time is up, Madam Chairwoman.

Mrs. LLOYD. Thank you very much, Mrs. Schneider.

One final question: I made the analogy of foregoing reprocessing that was made during the last administration. Would you consider that ordering such conversion falls in the same comparison?

Dr. BERNTHAL. Well, I—without making judgments on the decisions that were made with respect to reprocessing in the last administration—I would just say that that, to me, is a—an issue that was of far greater magnitude in the significance and importance in the big picture of proliferation than what we're talking about here.

In my judgment, what we're talking about in the case of the HEU/LEU conversion is something that everyone basically agrees and I should emphasize this: I don't think anyone disagrees that that is a worthwhile long-term objective. I think perhaps, with some reason, people are very concerned about how the NRC might go about achieving that worthwhile long-term objective.

I don't think it's quite in the same category of a major policy decision against reprocessing that in my judgment, at least, removed the United States as a credible and significant player in the larger world picture.

Mr. ASSELSTINE. Mrs. Lloyd, I would add on that that I think there's a matter of approach here as well with conversion to low-enriched uranium, we've tried to develop an international cooperation in this area and I think we have. President Reagan, in his nonproliferation policy statement in 1981, said that it is our policy to reduce the enrichment in research reactors at the earliest possible time. That's been the consistent policy of the executive branch right along.

And I think, by and large, we've received good cooperation from other countries. Other countries face some of the same kinds of difficulties that we've been discussing here today, have existing research reactors——

Mrs. LLOYD. You see it as more of a unilateral——

Mr. ASSELSTINE. I think this is more—less a unilateral approach than an approach to try and get cooperation by the other countries that we've supplied reactors to and that we've supplied the fuel to, to encourage them to reduce the enrichment levels in their facilities, and by and large, we're getting that cooperation.

But I have to say that to a certain extent, I think that cooperation in the future hinges upon the extent to which we also are willing to abide by the same kinds of terms and criteria that we're asking them to abide by. I had the opportunity last year to meet with the Director General of the EURATOM Supply Agency, and they have some of these research reactors, and one of the first questions he asked was: "What are you doing to reduce the enrichment levels of your research reactors in this country because you've been asking us to do that for ours and it's difficult and it's going to cost us some money and we want to be assured that you're doing the same thing here."

I know the State Department has said, in their comments, although they firmly support the President's policy to reduce the enrichment level at these facilities, that they're not real sure how much of a benefit it's going to be in terms of continuing to get cooperation from other countries. I think the Arms Control and Disamament Agency has been more positive in that regard. I've got a couple of letters that I could submit for the record that we've received from both of the agencies——

Mrs. LLOYD. Without objection, we'd be happy to have them for the record.

[The information follows:]

ASSISTANT DIRECTOR
UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY

January 12, 1984

Mr. Victor Gilinsky
Commissioner
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Victor:

I appreciate the information you forwarded to me relevant to NRC's consideration of a proposed rule on the conversion of certain domestic research and test reactors from HEU to LEU fuels.

ACDA fully supports the goal of the RERTR program to develop high density, LEU fuels which could be substituted for current HEU fuels. If successful, this program could lead to a substantial reduction in the traffic in weapons-usable HEU throughout the world.

Whereas DOE has been tasked with managing the technical aspects of RERTR, the State Department with support from ACDA has the primary responsibility for pursuading foreign reactor operators to accept reloads of the new LEU fuels as they become available. As one measure to speed the conversion of foreign reactors, guidelines were developed by the Executive Branch for use in considering requests for the export of U.S. origin HEU. These guidelines encourage the use of LEU fuels in all new research reactors and for future reloads in existing reactors when LEU fuels have been demonstrated which are similar in technical and economic performance to current HEU fuels.

Recently, foreign reactor operators have voiced interest in whether the U.S. is applying the same guidelines domestically and in what steps the U.S. is taking to convert domestic research reactors. Thus, the actions of the NRC on this matter can be expected to have some effect on our future negotiations with foreign reactor operators on the need and timing for converting their reactors.

In considering measures which will encourage conversion of research reactors, our international experience with RERTR participants has underscored the importance of being sensitive to the new licensing and funding issues. This includes trying to accommodate needs for HEU fuel during the transition period, rather than trying to force the pace to the point of creating friction. Based on the information which you forwarded to me, I understand that it may be undesirable for technical and/or economic reasons to convert all NRC licensed research reactors. However, even a few examples of successful domestic conversions early on could help pursuade others to follow through.

I look forward to working together with you and your NRC colleagues on this positive contribution to our long-term non-proliferation objectives.

Sincerely,

Lewis

Lewis A. Dunn

DEPARTMENT OF STATE
AMBASSADOR AT LARGE
WASHINGTON

January 13, 1984

Dear Mr. Palladino:

Thank you for your letter of December 2, 1983, concerning NRC policy on the use of high-enriched uranium (HEU) in NRC-licensed domestic research reactors and Commissioner Gilinsky's views on that subject. Commissioner Gilinsky has not communicated with me on this matter, so I cannot comment on his views. However, I am happy to comment on the thrust of the approach described in your letter.

The Department of State continues its strong support for the RERTR program. It is meeting with considerable success abroad and many of our trading partners have expressed appreciation for U.S. willingness to assist in developing the reduced enrichment fuel and the accompanying conversion program. While I would not suggest that the pursuit of the program domestically would have significant effect on the success of the program abroad, it could have some marginal benefit in demonstrating United States direct interest in pursuit of the program. The concerns and purposes behind our program abroad, of course, are linked to our overall non-proliferation efforts, and this effort will continue whatever the decision may be in respect to the domestic program.

The proposed rule for conversion of domestic research and test reactors which calls for replacement of spent HEU fuel with low enriched fuel, "if such action would be technically feasible with existing fuel technology at the time of refueling, and unless the licensee shows that the unique purposes of the project could not be achieved without using HEU fuel", would be compatible with the criteria used for establishing conversion feasibility and schedules in cooperation with foreign reactor operators.

I appreciate the opportunity to comment.

Sincerely,

Dick
Richard T. Kennedy

The Honorable
Nunzio J. Palladino,
Chairman,
Nuclear Regulatory Commission.

FOR RELEASE 9:45 A.M.
THURSDAY, JULY 16, 1981

THE WHITE HOUSE

Office of the Press Secretary

PRESIDENTIAL STATEMENT ON UNITED STATES NON-PROLIFERATION AND PEACEFUL NUCLEAR COOPERATION POLICY

Our nation faces major challenges in international affairs. One of the most critical is the need to prevent the spread of nuclear explosives to additional countries. Further proliferation would pose a severe threat to international peace, regional and global stability, and the security interests of the United States and other countries. Our nation has been committed on a bipartisan basis to preventing the spread of nuclear explosives from the birth of the atomic age over 35 years ago. This commitment is shared by the vast majority of other countries. The urgency of this task has been highlighted by the ominous events in the Middle East.

The problem of reducing the risks of nuclear proliferation has many aspects and we need an integrated approach to deal with it effectively. In the final analysis, the success of our efforts depends on our ability to improve regional and global stability and reduce those motivations that can drive countries toward nuclear explosives. This calls for a strong and dependable United States, vibrant alliances and improved relations with others, and a dedication to those tasks that are vital for a stable world order.

I am announcing today a policy framework that reinforces the longstanding objectives of our nation in non-proliferation and includes a number of basic guidelines.

The United States will:

- Seek to prevent the spread of nuclear explosives to additional countries as a fundamental national security and foreign policy objective.
- Strive to reduce the motivation for acquiring nuclear explosives by working to improve regional and global stability and to promote understanding of the legitimate security concerns of other states.
- Continue to support adherence to the Treaty on the Non-Proliferation of Nuclear Weapons and to the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco) by countries that have not accepted those treaties.
- View a material violation of these treaties or an international safeguards agreement as having profound consequences for international order and United States bilateral relations, and also view any nuclear explosion by a non-nuclear-weapon state with grave concern.

- Strongly support and continue to work with other nations to strengthen the International Atomic Energy Agency to provide for an improved international safeguards regime.

- Seek to work more effectively with other countries to forge agreement on measures for combatting the risks of proliferation.

- Continue to inhibit the transfer of sensitive nuclear material, equipment and technology, particularly where the danger of proliferation demands, and to seek agreement on requiring IAEA safeguards on all nuclear activities in a non-nuclear-weapon state as a condition for any significant new nuclear supply commitment.

I am also announcing that I will promptly seek the Senate's advice and consent to ratification of Protocol I of the Treaty of Tlatelolco.

The United States will cooperate with other nations in the peaceful uses of nuclear energy, including civil nuclear programs to meet their energy security needs, under a regime of adequate safeguards and controls. Many friends and allies of the United States have a strong interest in nuclear power and have, during recent years, lost confidence in the ability of our nation to recognize their needs.

We must re-establish this nation as a predictable and reliable partner for peaceful nuclear cooperation under adequate safeguards. This is essential to our non-proliferation goals. If we are not such a partner, other countries will tend to go their own ways and our influence will diminish. This would reduce our effectiveness in gaining the support we need to deal with proliferation problems.

To attain this objective, I am:

- Instructing the Executive Branch agencies to undertake immediate efforts to ensure expeditious action on export requests and approval requests under agreements for peaceful nuclear cooperation where the necessary statutory requirements are met.

- Requesting that the Nuclear Regulatory Commission act expeditiously on these matters.

The Administration will also not inhibit or setback civil reprocessing and breeder reactor development abroad in nations with advanced nuclear power programs where it does not constitute a proliferation risk.

The United States will support IAEA programs and other international cooperative efforts in the areas of nuclear safety and environmentally sound nuclear waste management.

To carry out these policies, I am instructing the Secretary of State, working with the other responsible agencies, to give priority attention to efforts to reduce proliferation risks, to enhance the international non-proliferation regime and, consistent with United States security interests, to re-establish a leadership role for the United States in international nuclear affairs.

FOR RELEASE 9:45 A.M.
THURSDAY, JULY 16, 1981

THE WHITE HOUSE

Office of the Press Secretary

FACT SHEET

PRESIDENTIAL STATEMENT ON UNITED STATES NON-PROLIFERATION PEACEFUL NUCLEAR COOPERATION POLICY

The President's statement today sets forth the basic elements of the Administration's policy on nuclear non-proliferation and peaceful nuclear cooperation.

Preventing the spread of nuclear explosives to additional countries remains a fundamental objective of the United States.

The President's statement reflects continuity in U.S. non-proliferation policy objectives for over three decades. It marks a shift in emphasis from the approach of the previous Administration, however, on how best to achieve these objectives. The Administration will seek to pursue non-proliferation more effectively by placing greater emphasis on:

- the need to improve regional and global stability and to reduce motivations that can move countries toward nuclear explosives;
- international cooperation as an essential part of strengthening the international non-proliferation regime; and
- the need to restore the U.S. as a reliable nuclear supplier under an effective regime of safeguards and non-proliferation controls.

Policy Guidelines

The President announced several policy guidelines.

1. The United States will seek to prevent the spread of nuclear explosives to additional countries as a fundamental national security and foreign policy objective.

As noted in the President's statement, further proliferation of nuclear explosives would pose a severe threat to international peace, regional and global stability, and the security interests of the United States and other countries.

2. The United States will strive to reduce the motivation for acquiring nuclear explosives by working to improve regional and global stability and to promote understanding of the legitimate security concerns of other states.

This shift in emphasis from the previous Administration means that increased recognition will be given to the fact that proliferation is an international political and security problem, and not just a matter of controls on the civil nuclear fuel cycle. The Administration will consider the range of U.S. diplomatic, economic and national security tools to reduce the motivations of other nations to develop nuclear explosives.

3. The United States will continue to support adherence to the Treaty on the Non-Proliferation of Nuclear Weapons and to the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco) by countries that have not accepted those treaties.

These treaties are major cornerstones in the international non-proliferation regime. The President also announced that the Administration will promptly seek the Senate's advice and consent to ratification of Protocol I of the Treaty Tlatelolco. This Protocol calls on nations outside the treaty zone to apply the denuclearization provisions of the treaty to their territories in the zone. It has been ratified by the United Kingdom and the Netherlands.

The United States ratified Protocol II to the Treaty of Tlatelolco in 1971. Protocol II basically calls upon nuclear-weapon states to respect the denuclearized status of the zone, not to contribute to violations of the treaty, and not to use or threaten to use nuclear weapons against parties to the treaty in the Latin American region. It has also been ratified by France, the United Kingdom, the People's Republic of China, and the Soviet Union.

4. The United States will view a material violation of these treaties or an international safeguards agreement as having profound consequences for international order and United States bilateral relations, and also view any nuclear explosion by a non-nuclear-weapon state with grave concern.

This represents a concern shared by the responsible members of the international community and underlines the gravity of United States concern. The Administration will work diligently with other countries to prevent such violations or nuclear explosions from taking place.

5. The United States will strongly support and continue to work with other nations to strengthen the International Atomic Energy Agency to provide for an improved international safeguards regime.

This reinforces the commitment of the United States to maintaining and strengthening IAEA safeguards and increased safeguards efforts. This is vital to have effective non-proliferation and nuclear cooperation policies, particularly as the magnitude and sensitivity of the IAEA tasks are increasing. The Administration will support the development by the IAEA of improved safeguards techniques, procedures and instrumentation, especially those needed for the larger and more sophisticated nuclear facilities that are likely to be deployed in the coming years.

The Administration will continue to support efforts under the auspices of the IAEA to develop effective regimes for international plutonium storage and improved cooperation in spent fuel management. It will also support the continuing work of the Committee on Assurance of Supply under IAEA auspices.

6. The United States will seek to work more effectively with other countries to forge agreement on measures for combatting the risks of proliferation.

To fulfill this objective the Administration will work actively with other nations to seek uniform non-proliferation conditions for nuclear supply. In particular, the Administration will work to prevent transfers to non-nuclear-weapon states of any significant nuclear material, equipment or technology that would not be subject to IAEA safeguards and to satisfy the following policy guideline.

7. The United States will continue to inhibit the transfer of sensitive nuclear material, equipment and technology, particularly where the danger of proliferation demands, and to seek agreement on requiring IAEA safeguards on all nuclear activities in a non-nuclear-weapon state as a condition for any significant new nuclear supply commitment.

As with the preceding guideline, the Administration will undertake concentrated efforts with other countries to fulfill this objective.

Enhanced Nuclear Cooperation

The President's statement also stresses the long-standing interest of the United States in cooperating with other nations in the peaceful uses of nuclear energy, under a regime of peaceful nuclear cooperation agreements and effective safeguards and controls. As the President's statement notes, many friends and allies of the United States have a strong interest in nuclear power and have, in recent years, lost confidence in the ability of our nation to recognize their needs. We need to restore confidence, trust, and mutual understanding in the field of international nuclear cooperation within the framework of effective safeguards and controls.

To accomplish this, the President's statement sets forth the objective of re-establishing the United States as a predictable and reliable partner for peaceful nuclear cooperation under effective safeguards. It notes a key reason for this position. If other countries go their own ways, United States influence will be diminished and its effectiveness in gaining the necessary support to deal with proliferation problems will be reduced.

To attain the objective of reliable and predictable supply, the President has:

1. Instructed the Executive Branch agencies to undertake immediate efforts to ensure expeditious action on export requests and approval requests

under agreements for peaceful nuclear cooperation, where the necessary statutory requirements are met.

The Administration will also normally authorize retransfers of nuclear material or equipment that precede use in reactors by the time an export license is issued.

2. Requested that the Nuclear Regulatory Commission act expeditiously on these matters.

In addition, the President announced that the Administration will not inhibit or setback civil reprocessing and breeder reactor development abroad in nations with advanced nuclear power programs where it does not constitute a proliferation risk. This also marks a shift from the approach of the previous Administration.

The President's announcement reinforces U.S. support for IAEA programs and other international cooperative efforts in the areas of nuclear safety and environmentally sound nuclear waste management. This will include support for the negotiation of a multilateral convention on nuclear safety cooperation and mutual emergency assistance; strengthened international cooperation in environmentally sound waste management; effective physical protection of nuclear material, including wide adherence to the Convention on the Physical Protection of Nuclear Material; and improved security measures for international transport of plutonium and highly enriched uranium. The Administration will also encourage the substitution of lower enriched fuels in research reactors at the earliest possible date.

The President has instructed the Secretary of State, working with the other responsible agencies, to give priority attention to efforts to reduce proliferation risks, to enhance the international non-proliferation regime and, consistent with United States security interests, to re-establish a leadership role for the United States in international nuclear affairs.

Under this mandate a number of reviews will be carried out. These include reviews of:

-- approaches for dealing with non-proliferation and nuclear cooperation issues in specific cases;

-- what steps might be appropriate, consistent with United States non-proliferation objectives, to facilitate or remove unnecessary impediments to commercial relations in the field of nuclear energy;

-- applicable laws, regulations and procedures to determine whether changes should be sought; and

-- possible approaches to develop a more predictable policy for exercising United States rights to approve reprocessing and plutonium use.

Mr. **Asselstine** [continuing]. That describe their positions, but my own view is, I think it is somewhat difficult for us to continue to ask the other countries to incur the expenses of reducing enrichment, which we all agree is a good thing to do for these facilities, without our at least applying the same kinds of standards here. And that means reducing enrichment if we can. If it is consistent with carrying out the purposes of these facilities and if it can be done reasonably and economically and the technology is there to do it.

Mrs. **Lloyd**. Well, thank you very much.

Dr. **Bernthal**. If I could just make one more comment by way of reassurance to the research community, and especially the university community, I suspect that had we approached this whole problem from a rather different standpoint in the beginning, as one where there was the possibility for the universities, with assistance from the Federal Government, to achieve a desirable objective that I think we have little disagreement over, and also perhaps achieve a certain upgrading in their facilities, they might have had a rather different attitude toward the way things have proceeded.

For my part, in my 20 percent role as a member of this Commission, I can assure you that, first of all, we've already laid down the ground rules as a Commission—and unanimously, I believe—that we're going to require funding before proceeding in this program; and second, I want to reassure the university community that I'm going to look very, very carefully at the procedural and licensing requirements that might be imposed, if any, indeed, are imposed, by any actions that we might take.

Mrs. **Lloyd**. That's a very constructive approach and we do commend you for your interest and the work and the thought that you've put into these proposals. Thank you for being with us.

Dr. **Bernthal**. Thank you.

Mrs. **Lloyd**. Mrs. Schneider has a witness from her district and we'd like to recognize you at this time, Mrs. Schneider.

Mrs. **Schneider**. I appreciate the opportunity to introduce out of order one of my fine constituents. The reason that I'm doing this is that unfortunately I have other demands on my time and, Mr. DiMeglio, you'll have the opportunity to testify a little later on after the second panel, but unfortunately, each Member does not get as illustrious an introduction unless, of course, the Member has the opportunity to sit on the committee, but I'd like to share with the Members in attendance that——

Mrs. **Lloyd**. We appreciate your participation and——

Mrs. **Schneider**. Sure thing.

Mrs. **Lloyd** [continuing]. And your being here today.

Mrs. **Schneider**. Well, Mr. DiMeglio has a bachelor of science in physics from Providence College and also has studied at the University of Rochester Health Physics and he's studied reactor design at Oak Ridge School of Reactor Technology.

Mrs. **Lloyd**. I must say, that's a good school. [Laughter.]

Mrs. **Schneider**. You have some bias there, but he is presently the director of the University of Rhode Island's—reactor and he's also the chairman of the national organization of Test, Research and Training Reactors and has been a member of the Rhode Island Atomic Energy Commission for the last 22 years, so it's a distinct pleasure to have such a well-informed individual to have the opportunity to testify and the fact that I can claim him as my own constituent is even better yet and I thank you, Madam Chairwoman.

Mrs. LLOYD. Thank you very much and we look forward to hearing from Mr. DiMeglio in our third—our fourth panel, and we'll call on panel—panel No. 2 at this time, the NRC Advisory Committee on Reactor Safeguards and others.

I understand that Mr. Jesse Ebersole is Chairman of the Nuclear Regulatory Commission's Advisory Commission on Reactor Safeguards will deliver the ACRS testimony; and Dr. J. Carson Mark, the chairman of the ACRS Subcommittee on Safeguards and Security, which I understand has some expertise in this field; and also Dr. Forrest Remick, a member of the Advisory Committee will be available for questions.

Also on this panel will be Dr. Edwin L. Zebroski, from EPRI. Dr. Zebroski has appeared many times before this subcommittee and we certainly welcome you back.

We welcome all of you, panel No. 2. It looks like a rerun of "I've Got a Question" here. [Laughter.]

We look forward to your testimony—"I've Got a Secret." [Laughter.]

We hope you don't have a secret today.

We do welcome all of you and your written statements will be made a part of the record and you may summarize as you wish. Mr. Ebersole.

STATEMENT OF JESSE EBERSOLE, CHAIRMAN, NUCLEAR REGULATORY COMMISSION, ADVISORY COMMITTEE ON REACTOR SAFEGUARDS; ACCOMPANIED BY DR. J. CARSON MARK, CHAIRMAN, SUBCOMMITTEE ON SAFEGUARDS AND SECURITY; AND DR. FORREST J. REMICK, MEMBER

Mr. EBERSOLE. Madam Chairman, we're pleased to be here. I'm pleased also to see a fellow Tennessean here. I'm an Oak Ridger myself.

Mrs. LLOYD. Well, I thought you looked like a pretty good witness. [Laughter.]

Mr. EBERSOLE. We're pleased to be here. I have a very short statement, only a page and a quarter, so I think it would be just as well if I read the entirety of it.

Mrs. LLOYD. Please proceed.

Mr. EBERSOLE. We're pleased to be here today to participate in your hearing on the conversion of domestic research and test reactors to low-enriched uranium fuel as noted in your letter of September 5, 1984.

I'm accompanied today by Dr. J. Carson Mark and Dr. Forrest Remick, members of the Advisory Committee on Reactor Safeguards, the ACRS. I've asked each to be prepared to respond to any questions that you may have.

I have this brief statement I'd like to make at this time and I would propose that a copy of the report of June 18, 1984, on the proposed rule for limiting the use of highly enriched uranium in domestic research and test reactors be made part of the record of your hearing:

Several of the meeting purposes identified in your letter of September 5 are more appropriately answered by others and I will thus limit my comments to purpose No. 1, the need for conversion and its impact, and purpose No. 5, who should pay for such conversions.

The ACRS believes that it is more appropriate to base the need for requiring owners of research and test reactors to convert from high-enriched uranium to low-enriched uranium on a national policy as articulated in the Nuclear Nonproliferation Policy Act of 1978 than it is to tie to an unidentified threat.

The conversion should be made on a gradual and orderly manner as funds and fuels become available. We believe that the owners of such facilities should have the option of conversion to low-enriched uranium or retaining the high-enrichment uranium and meeting appropriate security regs.

Although the ACRS did not consider specifically the potential impact of changing to a new fuel, the three of us believe that it will be necessary to carry out a new safety analysis to provide assurance that neither the fuel nor other components of the reactor will be subjected to damaging conditions during normal operation or during such departures from normal as may be reasonably expected.

We do not suppose that safe operation will be jeopardized by the sort of fuel changes proposed, but this will have to be confirmed for each different reactor design. This is an unrewarding chore which is likely to require several man-months of efforts, and in some situations, may require a man-year or so.

The ACRS believes that if the need for conversion is based on national policy, it is appropriate for the Federal Government to pay the cost of conversion, including such costs as the owners of research and test reactors may incur to accomplish the conversion.

That's the end of my statement.

[The prepared statement of Mr. Ebersole follows:]

TESTIMONY OF ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS) REPRESENTATIVES; MR. JESSE C. EBERSOLE, CHAIRMAN, ACRS, DR. J. CARSON MARK, MEMBER, ACRS, AND DR. FORREST J. REMICK, MEMBER, ACRS

Madame Chairman, we are pleased to be with you today to participate in your hearing on the conversion of domestic research and test reactors to low enriched uranium fuel as noted in your letter of September 5, 1984. I am accompanied today by Drs. J. Carson Mark and Forrest Remick, members of the Advisory Committee on Reactor Safeguards (ACRS). I have asked each to be prepared to respond to any questions that you may have. I have a brief statement that I would like to make at this time and I would like a copy of the ACRS Report of June 18, 1984 on the Proposed Rule for Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors made part of the record of your hearing.

Several of the meeting purposes identified in your letter of September 5 are more appropriately answered by others and thus I will limit my comments to purpose number 1, the need for conversion and its impact, and purpose number 5, who should pay for such conversions.

The ACRS believes that it is more appropriate to base the need for requiring owners of research and test reactors to convert from highly enriched uranium to low enriched uranium on National Policy as articulated in the Nuclear Nonproliferation Policy Act of 1978 than to tie it to an unidentified threat. The conversion should be made in a gradual and orderly manner as funds and fuels become available. We believe that the owners of such facilities should have the option of conversion to low enrichment uranium or retaining the high enrichment uranium and meeting appropriate security requirements.

Although the ACRS did not consider specifically the potential impact of changing to a new fuel, the three of us believe that it will be necessary to carry out a new safety analysis to provide assurance that neither the fuel nor other components of the reactor will be subjected to damaging conditions during normal operation or during such departures from normal as may reasonably be expected. We do not suppose that safe operation will be jeopardized by the sort of fuel changes proposed; but this will have to be confirmed for each different reactor design. This is an unrewarding chore which is likely to require at least several man-months of effort, and, in some situations, may require a man-year or so.

The ACRS believes, that if the need for conversion is based on National Policy, it is appropriate for the Federal government to pay the costs of conversion including such costs as the owners of research and test reactors may incur to accomplish the conversion.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

June 18, 1984

Honorable Nunzio J. Palladino
Chairman
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Palladino:

SUBJECT: ACRS REPORT ON PROPOSED RULE FOR LIMITING THE USE OF HIGHLY ENRICHED URANIUM IN DOMESTIC RESEARCH AND TEST REACTORS

During its 290th meeting, June 14-16, 1984, the Advisory Committee on Reactor Safeguards reviewed a proposed rule for limiting the use of highly enriched uranium in research and test reactors and a plan to increase security measures at nonpower reactors that use high-enrichment fuel. These matters were considered also during a Subcommittee meeting in Washington, D.C. on June 12, 1984. During our review, we had the benefit of discussions with representatives of the NRC Staff, affected users, and advocates of reduced availability of highly enriched uranium fuel. We also had the benefit of the documents referenced.

With regard to the proposed rule limiting the use of highly enriched uranium in domestic research and test reactors (contained in SECY-84-211), we believe it would be more appropriate to base the proposal on national policy as articulated in the Nuclear Nonproliferation Policy Act of 1978 than to try to tie it to an unidentified threat. If the proposal is based on national policy, it would be appropriate for the government to pay the costs of conversion from high-enrichment (HEU) to low-enrichment uranium fuel (LEU), including such costs as the licensees may incur to accomplish the conversion. The conversion should be made in a gradual and orderly manner as funds and fuels become available. The rule should provide the licensees with the option of conversion to LEU or retaining HEU and meeting appropriate security requirements.

If, as a consequence of changes needed to effect a conversion, a license amendment is required, then a hearing with the opportunity for public intervention is possible. Before the Commission adopts a rule which might permit unrestricted intervention, we recommend that the Commission obtain an evaluation of the course, nature, costs, and other relevant aspects of previous contested hearings involving nonpower reactors to determine if the hearings are serving their intended function effectively. It may be that the rules regarding hearings involving low power research reactors should be different than those for power reactors.

The exceptions in the proposed rule which would permit special purpose reactors to continue to use highly enriched uranium fuel are appropriate and should be retained.

With regard to the plan and schedule to increase security measures at nonpower reactors that use highly enriched uranium fuel, we find no objections to the proposals. We see no need to proceed on an expedited schedule.

Two of the Committee members who participated in this review are associated with affected institutions listed in the draft public announcement of this rule. Because they are rendering advice of a general nature from which their employers will gain no preference over others, they are not required to refrain from participating in this matter. Dr. M. W. Carbon did not participate in this review.

Sincerely,

Jesse C. Ebersole

Jesse C. Ebersole
Chairman

References:

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4. Report to NRC Commissioners, "Weapons-Grade Uranium on Campus - The Need to Convert Research Reactors to Lower Enrichment Fuels," by Daniel Hirsch, Stevenson Programs on Nuclear Policy, University of California, Santa Cruz, dated January 27, 1984
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8. Statement of William R. Mowry, License Administrator, GA Technologies, Inc. before the ACRS Subcommittee on Safeguards and Security dated June 12, 1984
9. Statement of Dr. David W. Hafemeister Before the NRC Regarding the Need to Convert Domestic Research Reactors from Highly Enriched to Low-Enriched Uranium Fuels, dated June 12, 1984
10. Statement of Paul L. Leventhal, Nuclear Control Institute, Before the Subcommittee on Safeguards and Security, ACRS, Regarding the Need to Convert Domestic Research Reactors From Highly Enriched to Low-Enriched Uranium Fuels, dated June 12, 1984

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

September 5, 1984

JESSE C. EBERSOLE

Mr. Ebersole was born in Belzoni, Mississippi, on March 2, 1916. He received his early education in Winona, Mississippi. He was a resident of Columbus, Mississippi, until his graduation from Mississippi State College in 1938, where he obtained a special honors degree in electrical engineering. He is a member of the Tau Beta Pi honorary engineering fraternity.

He was employed with the Tennessee Valley Authority (TVA) in 1939 in the Electrical Design Division. He was a resident of Knoxville, Tennessee, during this employment with TVA except for a four-year interval beginning in 1942 in the U.S. Army Air Force where he subsequently became a B-29 Flight Engineer.

He reentered TVA in 1946 as a design engineer on hydro and fossil plants, until joining the nuclear staff in 1955. He is a graduate of the 1956 class of the Oak Ridge School of Reactor Technology.

He worked on assignment to the Oak Ridge National Laboratory from 1956 to 1960 and was then appointed to direct the technical operating program for the Gas-Cooled Experimental Reactor at Oak Ridge. His work involved the design of experimental loops and programs, mostly in high temperature gas-cooled systems.

Mr. Ebersole's work became oriented to safety considerations early in his career. He has been an activist in the areas of integral systems engineering, system interactions, cascading failures, dedicated safety systems, and in functional-environmental separation of critical systems and related matters.

Mr. Ebersole was appointed to the Advisory Committee on Reactor Safeguards in April 1976, immediately after his retirement from TVA. He was reappointed in 1980 and 1984 and was elected Chairman of ACRS for 1984.

Mr. Ebersole's present residence is Oak Ridge, Tennessee.

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September 5, 1984

J. CARSON MARK

Dr. J. Carson Mark was born in Lindsay, Ontario, Canada, on July 6, 1913. He received a B.S. degree in mathematics and physics from the University of Western Ontario in 1935 and a Ph.D. degree in mathematics from the University of Toronto in 1939. He was a member of the Department of Mathematics at the University of Manitoba from 1938-43. From 1943-45 he was on the staff of the Montreal Laboratory of the National Research Council of Canada and transferred to Los Alamos in 1945 as a member of the war time British Mission.

Dr. Mark joined the staff of Los Alamos Scientific Laboratory in 1946 and served as the Division Leader of the Theoretical Division from 1947 to 1973. In 1973 he retired from the Los Alamos Scientific Laboratory.

Dr. Mark has also served as a member of the U.S. Air Force Scientific Advisory Board. He is considered an expert in the fields of hydrodynamics, neutron physics, finite group theory, and transport theory.

On February 2, 1976, Dr. Mark was appointed to the statutory Advisory Committee on Reactor Safeguards for a four-year term and was reappointed in 1980. He was elected Chairman for the year 1981.

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September 5, 1984

FORREST J. REMICK

Dr. Remick received his B.S., M.S., and Ph.D. degrees in mechanical engineering from Penn State. He also attended Lycoming College and the Oak Ridge (Tennessee) School of Reactor Technology.

Dr. Remick's professional career started at the Bell Telephone Research Laboratories where he was a mechanical engineer from 1955 to 1956. From 1956 to 1963 he held positions as Research Associate, Acting Director of the Nuclear Reactor Facility, and Acting Director of Curtiss-Wright Nuclear Research Laboratory at Penn State. From 1963 to 1965 he served as Associate Professor of Nuclear Engineering, Director of the Nuclear Reactor Facility, and Director of the Curtiss-Wright Nuclear Research Laboratory. In 1965 Dr. Remick was appointed Chief of the Training Section, Department of Technical Assistance, International Atomic Energy Agency in Vienna, Austria, a position he served in until 1967.

Since 1967 Dr. Remick has held a number of other positions of increasing responsibility at Penn State. These include Director of the Institute for Science and Engineering and Acting Director of the Center for Air Environmental Studies. Currently, he also holds the positions of Coordinator of University Energy Programs, Director of Intercollege Research Programs and Facilities, Acting Vice President for Research and Graduate Studies and Professor of Nuclear Engineering.

Dr. Remick has served on a number of committees and boards in the nuclear energy field including ten years as an Administrative Judge with the NRC's Atomic Safety and Licensing Board Panel, advisor to the National Academy of Sciences' National Research Council, member of EBR-II Review Committee, member of the Governor's Energy Council of the Commonwealth of Pennsylvania, member of the Atomic Industrial Forum's Committee on TMI-2 Recovery, member of the Institute of Nuclear Power Operations' Special Task Force on Training Alternatives, and is a member of INPO's Accediting Board. He was a consultant operator licensing examiner for the Atomic Energy Commission and the NRC for 14 years, and served from August 1981 until July 31, 1982 as Director of the NRC Office of Policy Evaluation where he reported to the five NRC Commissioners on the evaluation of technical and other policy issues.

His membership in professional societies include the American Society of Mechanical Engineers and the American Society for Engineering Education. He is a Fellow of the American Nuclear Society.

Mrs. **Lloyd**. Thank you very much.

I have these questions for all of you—oh, Mr. Zebroski, pardon me. Please proceed.

STATEMENT OF EDWIN L. ZEBROSKI, ELECTRIC POWER RESEARCH INSTITUTE

Mr. **Zebroski**. Thank you.

Madam Chairman, ladies and gentlemen of the committee, I'm very pleased to be able to offer comments on this subject and I guess I should start out by saying that I heartily endorse the immediately preceding statement. I think it's a very accurate and concise statement of a very reasonable position. I'd like to support that statement with some important background information.

Surveys by the Department of Energy and INPO have identified the need for approximately 5,000 trained professionals for the additional nuclear units coming into operation in the 1980's and the replacement for people already in the pipeline. The probable effect of the proposed rule on conversion to low enrichment is the loss of a further number of research reactors due to the open ended and unmanageable cost of litigation. Such litigation is likely in many cases wherever licensing changes or renewals are required and the effect on UCLA has already been alluded to at this meeting.

In response to the first question, the impacts of conversion, it is my view that there is no urgent need for the conversion process as now proposed if the available effective and practical alternatives with lower social and technical costs are used and would do much less damage to the scientific capabilities of our country.

In principle, these are possible under the proposed rule, but are fairly unlikely to happen because of the procedural obstacles.

Scheduled and amended security measures either can make or, in some cases already have made a situation in which there is negligible likelihood that small research reactors in the United States can ever plausibly be the source of material for a workable nuclear explosive device.

Our society has difficulty with the question of how safe is safe enough and the NRC paper on conversion talks about preferably zero risk and I think Commissioner Bernthal's statement seemed to also drift in that direction.

I have done a comparative analysis which suggests that the risk of diversion from university research reactors historically has been less than one-tenth of 1 percent of the risk which this country routinely accepts and that by simple administrative and technical measures other than conversion, that risk can be reduced considerably further.

I think I should also say, anticipating somewhat the later testimony, that the costs of conversion, I believe, are much, much, much higher than the NRC staff estimates, both the direct costs, the cost to the educational establishment and the indirect cost of loss of reactors. So the cost of the fuel is really a minuscule element in that overall cost picture.

I'd like to depart from my written text if I may, Madam Chairman, and——

Mrs. LLOYD. Please proceed and your written text will be made a part of the record.

Mr. ZEBROSKI. All right.

I'd like to depart for a moment if I may to summarize the risk assessment paper which is being given at a technical society meeting next week, since it's relevant to a couple of the points that Commissioner Bernthal raised. I may use the Vu-graph?

Mrs. LLOYD. Please, you may use the Vu-graph.

TABLE 1. RANKING OF DIVERSION EXPOSURES

	CATEGORY	ESTIMATED VALUE $P_{i,t}$ PER YEAR
I.	WEAPONS MATERIALS AND FACILITIES	.05
II.	LARGE TEST REACTORS USING HEU ABROAD	
	A. Unirradiated fuel materials	.005 *
	B. Irradiated fuel	.005
III.	LARGE TEST REACTORS - DOMESTIC	.0005
IV.	SMALL RESEARCH REACTORS AT UNIVERSITIES	.00005

*Subject to gradual reduction 1985-1990 by displacement with low enriched uranium.

Mr. ZEBROSKI. It's a hard subject to get in focus. [Laughter.]

This is simply a ranking of the conversion risk exposures which are related to the amount of material and the protective measures available and you see on a fairly reasonable basis that the big exposure is the tremendous tonnage flow of weapons materials across the face, not only of the United States, but of much of the world and which have been safeguarded for 30 years in this country and 28 years on the Soviet side.

The large test reactors using high enrichment abroad constitute a similar risk. There's approximately 2 tons of material typically in that pipeline historically and the ongoing effort in Department of Energy is aimed at reducing that exposure by converting that pipeline of unirradiated material to low enrichment.

None of the activities we're talking about will have any effect on the large tonnage of irradiated fuel which is present in spent-fuel pools overseas, total of 40 countries are involved, I believe, in over

100 sites. The large test reactors, domestic, the mostly DOE reactors, are next in line, but they are well-protected physically by physical protection at the sites and finally the small research reactors at universities represent about a tenth of a percent of that risk.

TABLE 2. Relative Cost vs. Risk Reduction Benefit of Current Commitments

Location	Type of Material At Risk	Weapons Equivalents Amounts Per Location	$/gram committed to reduce exposure
Domestic	Fuel for DOE Reactors	Several to Many	~0
Domestic	Fuel for non-DOE Reactors	0.1 to 0.2	> $100 *
Overseas	Future Fuel for Medium and high power Research & Test Reactors	Many	~$20
Overseas	Spent Fuel Containing Highly Enriched U-235	Many dozens	< 0 **

*Based on ref. (1), if promulgated without changes.

**U.S. requires substantial payment to accept the return of such fuel.

Mr. ZEBROSKI. Commissioner Bernthal also alluded to the need for more thorough cost-benefit analysis. This is at least a rough cut at that kind of a cost/benefit analysis and I'll just focus your attention on three of those lines, since it would be a long discussion to go through them, but very conservatively, our society, one way or another, will pay about $100 a gram for the material removed from service in the research and test reactors, the low-power research and test reactors. These are sites where the typical inventory can easily be made less than one-tenth or two-tenths of a weapon equivalent. That is, you'd have to steal between 5 and 10 of these reactors and do a wonderful job of recovering the material to have any plausibility of making a nuclear device.

On the other hand, overseas, the inventory of material in process—that is, unradiated, which has run as high as 2 tons, is clearly a large target for improvement and our investment just in the R&D of that is now equivalent to about $20 a gram for the material which eventually will be taken out of service over the next few years.

But the dominant risk in my view continues to be the spent fuel containing highly enriched uranium. At least 6 tons of this material is overseas; it may be as high as 10 tons in the 1980's because of the pipeline effect.

Right now, we're assigning a negative risk value to this material because instead of trying to get it back and expending funds to get it back, we're charging the people overseas so much that they don't send it back, and I'd like to resume my prepared statement.

Mrs. LLOYD. Mr. Zebroski, would you elaborate on your statement that we're charging them so much they don't dare ship it back.

Mr. ZEBROSKI. Yes, ma'am.

Three main concerns are evident on the effect of the proposed conversion rule. First, the risk-defining scenarios have not been explicitly stated by the NRC, despite requests from the university community and no explicit account has been taken of the effect that two successive stages of improved security measures and particularly the substantial reductions in the inventory of unirradiated materials, which have already been implemented, and I believe that total inventory can be readily reduced to below 10 kilograms so that in principle, you'd have to steal all the reactors in the country and you still couldn't make a weapon.

With the appropriate measures of security levels, the reactors with lifetime cores, which nominally have much less than a kilogram on site, may reasonably be found to be exempt from requirement to convert to low enrichment, at least in the near future.

For the two or three reactors which have a hard time meeting the test of low inventory, I believe they should reconsider an option which is allowed for in the proposed draft rule, but which will have a hard time being implemented, which is to use enrichments in the neighborhood of 40 or 50 percent, which, for those few reactors, would also meet the test, but you'd have to steal all of the reactors and still not be able to make a weapon.

That—that option also has not been evaluated in the NRC staff papers, to my knowledge.

The second concern I have already mentioned is that the cost social and environmental impacts of the rule as drafted have not really been adequately evaluated in the documentation to date, particularly the costs, I believe, will be much higher and I believe you'll hear about that in the fourth panel.

The possible loss of research reactors was merely listed in the staff documentation without analysis of the size or the consequences of this effect.

The third concern I have is the assumed ineffectiveness of security measures. I think we're being panicked by the bombings in Lebanon, to put that succinctly. When you look at how many reactors and how much material you have to accumulate, the real risk that I see as a risk analyst in this is that we have set a stage for potential panic if a—even an amateurish attempt, an intrusion or what have you, at a research reactor is interpreted by apparently officialdom as a near miss to an instant bomb, we've laid the seeds for panic, which is truly unwarranted. To me, that is the real risk to society in this business right now.

High-tech facilities of many kinds have been subject to malicious acts, graffiti, vandalism, damage or thefts of equipment, injuries to personnel. Good security measures against such occurrences at research reactors and other technical facilities are prudent and needed, regardless of the enrichment level of the fuel.

Finally, I think in discussing this with NRC folk, we have to say that a Government body does not usually own up to responsibilities of possible misinterpretation or exaggeration of its efforts which are taken in good faith in attempting to limit public risks. However, if you have a choice of alternatives of actions which don't have as byproducts the risk of panic, those alternatives ought to get a very serious look.

I've been asked to respond to the question of who should pay for the conversions and I'd like to dodge that question directly, but substitute subquestions which bear on it, as to what kinds of costs are involved and how are they distributed. I'll just make the brief remark that they are distributed not just in 1 year, but they will be spread over about a 5-year period involving a very substantial diversion of people from educational research efforts, and I think Mr. DiMeglio will cover that topic.

To what extent can the cost be minimized or avoided by practical administrative measures and procedures? I think I've mentioned several of these. I think the—giving credence to definite security threats and designing the security measures to be responsive to them, minimizing the inventory—there's a good many measures short of the actual costly and technically very difficult conversion, at least for some reactors, are available, and I believe those measures should be exhausted before mandating a conversion.

Finally, the tough question is who should pay and that's an awkward question to ask; how you should pay for something that you don't feel ought to be done, but I think the precedent for paying for fuel is well established. In a sense, the research reactors, the fuel, the people, the training, the educational capabilities are a national investment, a great deal of it being Federal, but also a good deal being State investment and I believe the committee should give consideration to possible mechanisms for funding some of the inevitable litigation costs which are present procedures forced upon the community as a way of protecting that very substantial investment and without which, as in UCLA, we will lose more reactors.

Thank you, Madam Chairman.

[The prepared statement of Mr. Zebroski follows:]

Testimony for the Committee on Science and Technology, U.S. House of Representatives, September 25, 1984.

Subject: The Conversion of Domestic Research and Test Reactors to Low Enrichment Uranium Fuel

By: Edwin L. Zebroski, Energy Studies Center, Electric Power Research Institute

General Concern on the Impacts of Conversion

Research reactors and the associated facilities and professional capabilities are an important part of the national capability for training qualified personnel. Surveys by DOE and by INPO have identified the need for approximately 5,000 trained professionals for the additional nuclear units coming into operation in the 1980's. The probable effect of the proposed rule on conversion to low enrichment is the loss of still further research reactors due to the near-certain exposure to unmanageable costs of litigation. Such litigation is assured in many cases wherever license changes or renewals are required, or such licensing changes can be alleged to be required. For example, a recent casualty of such litigation, after several years of hearings (and several hundreds of thousands of dollars in legal costs) is the reactor at UCLA.

The invitation from this Committee asked for response on two of the five specific questions;

(1) "The need for and potential impacts of requiring owners of research and test reactors to convert from highly enriched uranium (HEU) fuel to low enrichment fuel (LEU)."

(5) "To identify who should pay for such conversions, if required."

Question #1. Need for and Impacts of Conversion

In respect to the first question, it is my view that there is no urgent need for the conversion process as now proposed, since effective and practical alternatives with lower social and technical costs are available. For example, the scheduled augmented security measures can make, (or in some cases, may have already made) a situation in which there is a negligible likelihood , that small research reactors in the United States

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*This topic involves certain factual background. However, some portions of it involve judgements and opinions based upon individual background and experience. My comments on this topic, accordingly, are my own personal views, and do not necessarily represent the views of EPRI or its member sponsors.

can plausibly become the source of material for a workable nuclear explosive device.

Our society, (and with it our regulatory legislative and judicial establishment), is in considerable disarray on how to define or specify "how safe is safe enough". For example, the NRC staff paper on conversion to low enrichment uses the phrase "preferably zero risk". The proposed rule on conversion is consistent with an apparent attempt to reach such an objective, if the risk is defined in a particular narrow way. A broader view of the risk, in perspective to other closely related risks, may suggest that the risk reduction benefit for domestic conversion is rather small, and the total costs are rather high. One cannot fault the NRC for striving to reduce any risk within its jurisdiction, even if that risk is a small part of the total risk picture, and even if the costs are high, and even if there are possibly some counterproductive effects nationally. Qualitative estimates and rankings of such risks are provided in a separate paper which is being submitted. In a national context, serious consideration should be given to the broader aspects of this issue. This Committee represents the most important forum for such broader considerations at this time.

Impacts of the Proposed Rule

Three main concerns are evident on the effects of the proposed conversion rule, as it is now formulated. These concerns are:

(1) The risk-defining scenarios have not been explicitly stated by the NRC, despite several requests from the university community. No explicit account has been taken of the effect of two successive stages of refinements in security measures and the large reductions in the inventory of materials, not actually in the reactors, that have been effected. Significant additional security measures were implemented in 1983. Additional augmented security measures are available and in process. These are modest in cost, and have already been implemented at some facilities.

With the appropriate levels of security measures, the reactors with lifetime cores, and which have normally less than one kilogram of unirradiated fuel on site, may reasonably be found to be exempt from a requirement to convert to lower enrichment, until and unless the fuel is replaced for other reasons. This exemption from near term conversion is reasonable, I believe, since the amount of U-235 in several of these reactors, possibly as many as five of them - would not support the making of a single "low technology" nuclear explosive device.

For the reactors which do not meet the test of small inventory, I believe that it is important to reconsider the use of enrichments in the neighborhood of 50% U-235. This is sufficiently low to make the production of a working nuclear explosive highly implausible due to the physical difficulties and due to the amounts of material required.

An enrichement level near 50% also permits the replacement fuel for research reactors to stay within the same design and performance characteristics of the present high enrichment fuel. This also avoids most of the exposure to licensing changes and unproductive litigation which is likely to be provoked by the changes required to achieve the use of 20% enrichment in some reactors.

(2) A second concern is that the cost, social and environmental impacts of the proposed rule, as drafted, have not been adequately evaluated in any of the documentation to date. Even in the most optimistic case of minimal licensing change involvement, the cost in terms of staff time and diversion of personnel and resources from educational activities I am told, is much greater than estimates available in staff papers. In the event a licensing question is present, or can be alleged, then the cost in terms of resources and staff time can readily rise to levels that are beyond the means of many universities. Even if a university has adequate resources, it becomes a legitimate question whether diversion of those resources to the litigation of issues (and which have repeatedly been litigated in other places previously) is a prudent use of their resources. I believe that the evidence is compelling that additional numbers of research reactors are likely to cease operation, and cease to be available for training, research, testing, or for the production of radioisotopes for research and medical use. The possible loss of these capabilities has been listed in the staff documentation but without analysis of the size and consequences of the social, financial and educational impacts. (Full evaluation of both the direct and indirect costs and social impacts is normally consistent with the NRC's own procedures).

(3) A third concern regards the assumed ineffectiveness of security measures. There are extensive readily available, and to considerable extent already implemented security measures that were substantially augmented in 1983. To lose enough material to make a nuclear explosive plausible, one would have to give credence to the possibility of thefts from a

considerable number of reactors simultaneously or in very close succession. One would have to assume no significant provisions for efforts for the timely detection and response by civil and military authorities. Such assumptions also discount the inherent mechanical barriers of physical access, shielding, alarms, guards, and communication systems.

The NRC staff has testified that there has been no evidence of a plausible theft or diversion attempt at any research facilities in the nearly three decades that such facilities have been in existence. They further testify that intelligence agencies say they have no indication of individuals or groups which might have such intent to attempt, or capability to execute. Nevertheless, the apparent credence being given to the remote possibility of successful theft or diversion from several research reactors simultaneously, (which together do not hold enough materials to make a single nuclear explosive) can set the seeds of future panics. High-tech facilities of many kinds have been subject to malicious acts, including: graffiti, vandalism, damage or thefts of equipment, and injuries to personnel. Strong security measures against such occurrances research at research reactors are prudent and needed regardless of the enrichment level of the fuel being used. Sooner or later, one or more research reactors will have such experiences. If credence is given by authorities to instant bombs from insufficient material, then future panics are likely to be an unfortunate by-product. The rule may unintentionally and indirectly contribute to a real increase in public risk (possible actual deaths and injuries in traffic accidents resulting from hasty and unwarranted evacuations).

- A government body does not bear responsibility for possible misinterpretation or exaggeration of any of its actions which may be taken in its function of limiting public risks. However, given a choice of alternatives, those which minimize the chance of unfortunate by-products should have considerable attention and priority.

Question number 5 in the letter of invitation is: "to identify who should pay for such conversions, if required". Before considering the question of who should pay, it may be instructive to consider several implied sub-questions. For example:

(1) What kind of costs are involved and how are they distributed among the different types of facilities and how are they distributed in time?

(2) To what extent can some of the costs be minimized or avoided by practical and available administrative, regulatory or technical measures and procedures?

(3) There is a question of finding a feasible mechanism for funding the excessive procedural and legal costs which are an unavoidable consequence of the proposed rule as it is now formulated.

In respect to (1) above: the dollar values of costs foreseeable by universities, this topic will be covered by testimony from the university community. I will simply observe that for some reactors, which can accept the fuel at lower enrichment without change in configuration, the cost impacts (except for the purchase of the fuel itself and its fabrication costs) can often be within the means of the university or research reactor owners. The impact is the diversion of staff time and efforts-perhaps several professional man-years from educational and research work. However, even this relatively favorable result is contingent upon comprehensive efforts by all parties - DOE, reactor owners, and NRC to avoid making changes which could open allegations that licensing changes are required.

An additional group of reactors will be subject to relicensing. This may be due to the need to change fuel or cooling system configuration (where there is insufficient volume available in the existing fuel configuration to accommodate 20% enriched fuel). For still other reactors renewal of license is required in the normal course of events due to expiration of the original license. It appears likely, from discussions in the university community, that few university departments will have the resources to bear the legal costs involved in extended licensing hearings. (Such hearings can also include allegations on the need to restudy all reactor safety questions, environmental impacts, hypothetical accidents, etc).

Finally, it is noted that the cost effects of a mandated change to low enrichment will be felt over a period of time which may extend as long as five years in some cases. Additional time is required to solve the evident problems of design, proof-testing, and to establish the availability of low enrichment fuel fabrication involving different materials and processes for some of the research reactors.

In respect to the second sub-question on costs, there are a number of actions available, principally to NRC, but some also involving DOE, which could in principle substantially reduce the costs without material loss of effectiveness, if conversion were to be mandated by NRC. Some of these actions were implied in the first half of this discussion on the question of need for conversion. For convenience the potential (and recommended) actions are listed here;

(A) Reconsider whether reactors with lifetime cores and with minor inventories of unirradiated uranium can attain or have attained sufficient augmentation of safety by thorough and intelligent application of available, practical and cost-effective security measures.

(B) Reconsider the enrichment level for those reactors for which substitution of 20% enrichment is technically very difficult. It now involves changes in fuel and reactor configuration, continued extensive testing, for some years, and questions on the availability of proven and warranted supply of fuel fabrication. For these cases, the use of enrichments in the neighborhood of 50% substantially reduces the complexity of the technical and fabrication problems, greatly reduces the cost and duration of the associated R&D, and can achieve a large fraction of the presumed reduction and risk of diversion or theft, compared to that resulting from the use of 20% enriched fuel.

(C) A compelling reason for the consideration of enrichments near 50% is that this option is likely to be practical, for some reactors, 3 to 5 years sooner than 20% enrichment. The trade-off is more immediate reduction in the (already small) residual risk, versus a slightly better but delayed improvement.

This is not to say that hypothetical scenarios for such risks cannot still be alleged for 50% enrichment (or even 20%). However, risk reduction benefit to cost ratio of the 50% option is is likely to be larger than an inflexible mandate for conversion to 20% enrichment. Social and educational costs are much lower, as well as costs for R&D, and procedural exercises. Also the actual costs of new fuel procurement are lower, and fuel reliability is likely to be better since the needs for novel or exotic materials, processes and performance conditions are minimized.

In respect to who should pay, if conversion is nevertheless mandated, the following observations apply:

(1) The existing community of research and test reactors, represents a substantial national asset. It represents the investment of considerable Federal and local funds in facilities, materials, and research equipment as well as in personnel and research and teaching experience. Additional investments by state and local agencies and research organizations, and by universities are also represented. If the rule is promulgated as now drafted, I believe significant portions of this investment will be wasted. A decision by the NRC to mandate conversion, as now formulated, is tantamount to an unintended judgement that the waste of these national resources is not important; that the loss of the educational and research and medical capabilities is unimportant, and that the need to train and educate some added thousands of people for safe and economic operation of the existing nuclear capacity will somehow occur even if some additional facilities are lost and experienced staffs are dispersed. Obviously the NRC would not make such judgements explicitly. However, the purview of this Committee can include an consideration of whether a course of action which appears tantamount to reduction in research reactor capabilities in this country is truly in the public interest.

There is a broader social impact, I believe, in the further reduction in domestic capability and technical skills in nuclear related R&D, testing, and medical uses. The center of gravity of such capabilities is already trending overseas. Further reduction in the domestic capability can have large, even if not directly calculable impacts. For example, possibly smaller numbers and more limited selection of people being trained, and some of them may find available less comprehensive education and training. This can reflect itself in less efficient operation of the country's large investment in nuclear reactors, both for civilian power, and for research and military purposes as well.

FUNDING

There is extensive precedent for federal funding of facilities, fuel, research equipment, and research grants at non-government research reactor facilities. The draft rule indicates the expectation that the DOE would fund the replacement fuel, and I support this assumption. However, to my knowledge, there are few precedents for Federal funding of technical staff and legal costs which are incurred whenever licensing hearings are protracted (for example, as at UCLA) and which are likely to be the dominant costs in some cases.

Finally, despite the lack of precedent, it would seem appropriate for this committee to consider establishing mechanisms for funding support for universities which do not have the resources to support the litigation which is likely, if the rule is promulgated as now drafted. This, I believe, is necessary if an existing national resource in facilities and talent is to be protected. Since there is already largely an investment of federal funds, a rationale for further assistance to defend this investment against wasteful losses may be justifiable.

For Presentation at Annual Meeting of The Society for Risk
Analysis - October 1, 1984 Knoxville, Tennessee

ANALYSIS OF RISKS OF DIVERSION OF PLUTONIUM OR HIGHLY ENRICHED URANIUM

E. L. Zebroski
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ABSTRACT

The production of a nuclear explosive device requires a range of specialized skills and facilities and a sufficient quantity of concentrated fissionable material. Significant amounts of such materials exist in hundred of locations, in a variety of forms including mixtures with nonfissionable materials and with radioisotopes. Nuclear weapons start with pure metallic materials of predominantly a single isotope (uranium-235 or plutonium-239). Chemically or isotopically diluted materials either require larger amounts of fissile isotope or else cannot be made to produce an explosive reaction without extensive processing involving sophisticated techniques and facilities. Obstacles to diversion of fissionable materials include combinations of physical security, guards and defense forces, accountancy, diluents, limited amounts of material in any one location, and timely detection and forceful reaction to attempts at diversion or theft.

A generalized risk assessment model is developed, incorporating the main factors that influence the probability of successful diversion. A roughly inverse relationship is involved between the amount of material potentially seized or diverted and the levels, skills, facilities, and resources required to make a workable

nuclear device. Absolute probabilities are indeterminate. Experience indicates an upper bound of about 1.6×10^{-6}/year/weapon-equivalent amount of material. Inequality relationships can be used to develop relative rankings and semiquantitative magnitudes of diversion risks.

Small university research reactors appear to contribute less than 0.1% of the total diversion risk of U.S. materials. Limiting the amounts of material at any one university location is practical so that thefts from several--perhaps half a dozen--reactors would be required to make a single explosive device plausible.

A related, nonnuclear risk appears relatively likely, arising from the likelihood of unwarranted public overreactions to a variety of actions from vandalism to attempted thefts. These reactions are likely, given the present levels of discrimination on this topic.

Cost/benefit relationships are also derived. These exhibit disparities of several orders of magnitude in the ratios of commitments made or planned to the size of risk exposure reductions attainable.

KEY WORDS: Diversion; Weapons Material; Nuclear Bombs; Research Reactors; U-235; Plutonium.

Probabilistic Formulation of Risk Exposure

The main factors which affect the likelihood of successful diversion, or theft of material to the end result of a workable nuclear device are exhibited in equations (1) through (4).

$$P_{tot} = \sum_{i,t} P_{i,t} \; T_i \qquad \text{(Eqn. 1)}$$

$$P_{i,t} = \frac{d_{i,t} \; A_{i,t}}{M_b} (1 - r_{i,t}) \; Q_{i,t} \qquad \text{(Eqn. 2)}$$

P_{tot} = Total probability of successful diversion of material from all i facilities in time interval t.

$P_{i,t}$ = The probability of successful diversion of material to produce n workable nuclear explosive devices from location i, in time interval t.

$A_{i,t}$ = The amount of weapons-usable material contained in location i, during time interval t.

M_b = The mass of fissile material required for a nuclear explosive device of type b.

$d_{i,t}$ = The probability of access for theft or diversion from location i in time interval t, of amount $A_{i,t}$.

$r_{i,t}$ = The probability of detection and protection or recovery of material $A_{i,t}$, given that access has occurred or been attempted.

$Q_{i,t}$ = The probability of success in assembling a workable nuclear device given mass M_b.

T_i = Time of exposure of amount $A_{i,t}$ at location i.

There is a further important relationship affecting the value of M_b for a given diversion attempt

$$M_b = \frac{M_o}{f(R,S,D,E,G,T)} \qquad \text{(Eqn. 3)}$$

where M_o = just critical mass of material without efficient reflector and at nominal density

$f(R,S,D,E,G,T)$ = a complex relationship generally proportional to the product of the availability of resources R, Scientific and technological skills S, specialized data D, specialized equipment and facilities E, specialized materials G, and time T, available to accomplish the design, processing, testing, and assembly.

Also $Q_{i,t} \propto f(R,S,D,E,G,T)$ (Eqn. 4)

And for $M_b \ll M_o$; $Q_{i,t} \cong R \times 10^{-9}$

where R = resources in \$

The expressions given can not be quantitatively evaluated in closed form. However, they permit several of order-of-magnitude qualitative or ranking comparisons that can be useful in decisions on risk management activities.

Assumption of a First Law of Risk Management

The value of these inequalities assumes their use in the ideal mode of rational risk management to optimize the total amount of safety which is obtained for the total effort available or expended. This might be referred to as the "first law of risk management," which can be formulated as follows: "the relative effort applied to limit or control a given risk should be in proportion to the product of the relative size of the risk and the fractional reduction in that risk achievable for the effort applied."

It is recognized that such a first law is very limited in real world application for several reasons. The discipline for establishing relative risks within a given field of or type of risks is now often practical, but is used only sporadically in practice. The problem of developing relative risks between different areas or functions of society, is still in its infancy, is overlaid with subjective values and customs, and has virtually no impact in public risk management and policy. Exogenous factors commonly drive the priority and resources devoted to risk management activities of various types. The extended literature on the influence of risk perception highlights the large gaps between rational deployment of effort in risk management and actual current practices. This analysis adds to the literature of such gaps.

Recognizing all of the foregoing limitations, nevertheless, it is assumed that awareness of the relative rankings of risk exposures to a common set of hazards can be useful to policy makers and in drafting specific rules, regulations, and procedures which indicate the type and intensity of efforts to be applied to various risk management activities.

Effects of the Controlling Factors

The general relationship equation (1) can be interpreted as a measure of the annual probability that significant amounts of fissionable material might be seized, stolen, or diverted, from locations holding such materials, and in amounts sufficient to produce one or more nuclear explosives. Recent attention on improvement in security measures in certain weapons storage facilities are aimed at reducing the probability of success of access ($d_{i,t}$). However, a little reflection will suggest that vaults or passive measures can always be breached if the incentive is large enough, and that the factor ($r_{i,t}$) of detection, recovery and reaction forces is at least equally important in preventing successful theft or diversion.

Another factor, ($Q_{i,t}$), is extremely important in evaluating risks at locations at which only small amounts of material are present. Given a relatively large amount of material, an explosion with some degree of nuclear yield might be produced, perhaps not as a garage operation, but certainly with the materials and equipment available in almost any modern university with science and engineering departments. For this reason, much more intensive protective measures (affecting $d_{i,t}$ and $r_{i,t}$) are appropriate for facilities which routinely contain many times the amount of material (M_b). Given 50 or more kilograms of highly enriched U-235, it becomes plausible that an adequately educated but inexperienced team of people could produce a single nuclear explosive. To be sure, the reliability of the device might be uncertain, the yield might range anywhere from ability to destroy several city blocks to a nuclear "fizzle" with a nuclear yield hardly more than the chemical explosive used. Nevertheless, even such a primitive device could have major public and governmental impacts. For perspective, it should be noted that similar capacity for blackmail, terror, or damage can be obtained with much smaller initial resources and using much more readily available materials and means.

With smaller quantities of highly enriched U-235, say 20 to 30 kg, (or more to allow for processing losses), somewhat higher levels of skills and facilities are required, and there is greater need for specific physical data and calculations and process information for which the essential know-how is not available in the open literature. Unless it is further assumed that a sizeable team of people with extensive experience in a national weapons program are available, the time required to attain a plausibly workable device, and the probability of failure, both increase substantially.

For still smaller amounts of material, say 10 to 20 kilograms of U-235, net after processing losses, the requirements are sharply increased for specialized skills, data, facilities, and materials. As far as can be deduced from the historical record, this stage of development in each of the weapons countries has required an all-out national effort with essentially unlimited financial and material resources. Total times on the order of three years or more were required for a first successful effort in each of the countries which are currently weapons producers. The focus on the production of fissile materials tends to overlook the parallel, and in some respects more difficult developments required to produce the actual device.

The replication of such results by a team with all of the relevant data and experience, obviously would take less time and effort. However, it is highly implausible that a limited team of people with subnational levels of skills, resources, and facilities could accomplish this task in a short period of time. Three to five years can plausibly be regarded as being a minimum to achieve an appreciable probability of success.

The well-publicized assertions by a former Los Alamos employee that small amounts of materials could readily be converted to nuclear weapons given readily available unclassified data, skills, materials, and facilities, appears to have hidden within it several interesting assumptions. The most basic assumption required (to give a significant probability success) is that a substantial team of people with a wide range of theoretical, engineering, chemical, metallurgical, and mechanical skills and directly applicable experience are available--presumably recruited from a national weapons laboratory such as Los Alamos--and that they willingly cooperate in a clandestine subnational or terrorist effort. A second assumption is that such a team would bring with it a large volume of detailed physical data, and nuclear, chemical, metallurgical, and specialized know-how, including explosives and hydrodynamic technology. A further hidden assumption appears to be that resources, and facilities--often estimated to be in the range of several hundred million dollars--are available to such a team, and that no obstacles in procurement, or hazards of detection of such activities are operative. For the case of limited amounts of fissile material requiring highly sophisticated design, fabrication, assembly, and packaging, the probability $Q_{i,t}$ can be represented as a judgment approximately by the product of resources available in dollars times 10^{-9}, and three to five years' time.

Alternate Paths and Diversion Scenarios

For plutonium-239 as the target material for theft or diversion, many of the same considerations apply, except that the reference mass of material M_b is less than 1/3 as large as for U-235. This highlights an interesting strategic question on the motives and tactics of a would-be diverter. If weapons of medium or high technology, are desired, able to work with relatively small masses of material, then diversion of small amounts of material (say less than 50 kg of U-235) is unprofitable, relative to the overall effort required. A more direct, secure, and expandable route is the development of dedicated facilities to produce U-235 by any of a considerable number of proven enrichment processes. Equally simple, at this level resources, is the production of plutonium in a low-temperature, low-technology production reactor. The scenarios which lead to substantial prospects of success in diversion can be qualitatively ranked as follows:

(1) A national decision to "go for nuclear weapons" by seizure of substantial stockpiles of existing nuclear weapons already produced by one of the present nuclear weapons countries, and stored and deployed in several hundred locations throughout the world.

(2) A national level decision to "go nuclear" by clandestine development of as much as possible of the theory and technology of the device in a secret

manner, followed by seizure of major amounts of fissile material (for U-235 ranging from several hundred to several thousand kgs) which may be available in aggregate as raw material, fabricated fuel, and spent fuel associated with research and testing reactors. Under similar circumstances, an alternate decision may be to seize substantial tonnages of spent fuel from power reactors, with the intention of reprocessing to extract plutonium, using previously built and tested facilities. Both of these options involve large risks of international interventions.

(3) A national, but more likely subnational, faction decision to seize relatively small amounts of material (for example, 25 to 100 kgs of U-235) which may be available in research testing, or prototype reactors.

(4) Subnational factions or terrorist groups' decision to steal or divert relatively small amounts of material from fabrication stockpiles, or research and test reactors for criminal, terrorist, or ideological ends.

(5) Diversion or theft of material from U.S. medium or high-powered research or test reactors.

(6) Diversion or theft from low-powered U.S. research reactors commonly at universities.

We note that each scenario involves somewhat different objectives, requirements, and resources. It is important in assessing risks of various scenarios to use self-consistent sets of assumptions. For example, a highly skilled, highly resourced group with near-national capabilities would have little motivation for thefts of small quantities of material, since this would rate poorly relative to a self-production approach or relative to seizure from locations with large amounts which could be expanded to a significant offensive or defensive capability.

Limiting Value Approach to Aggregate Historical Exposure

A large number of nuclear weapons are deployed in several hundred locations within the United States. All but three states are known to have several such locations. In addition, weapons are deployed in over 100 locations in Europe, and several hundred locations in Southeast Asia, not counting ships at sea. Given the buildup of production of nuclear warheads (including aircraft-carried bombs, artillery shells, and warheads for ballistic and cruise missiles), something in excess of 30,000 such devices have been produced in the United States and stockpiled or deployed. Allowing for the buildup over time since 1945, we can estimate a cumulative exposure of approximately $4x10^5$ weapon-years has occurred. We can take account of raw material and material in production and rework pipelines by dividing the amount of such materials by the average mass required for a weapon. This gives a further estimate of $2x10^5$ weapons-equivalent years of exposure. Similarly, we can estimate the exposure for non-weapons materials in several categories. For example, highly enriched materials supplied for research in test reactors overseas are approximatley $1.5x10^4$ weapon-years equivalent. Domestic research and test reactors (medium and high power) constitute about $1.5x10^3$ weapon-year equivalent. Small low-powered university type research reactors give a cumulative exposure of less than $4x10^2$ weapon-year equivalents.

The overall cumulative exposure is roughly $6x10^5$ weapon-years exposure to date. Given that no successful diversion resulting in a nuclear device has occurred, the current limiting value for diversion or theft is about 1.6×10^{-6} per weapon or weapon equivalent, per year.

Derived in the same fashion, the current annual exposure is approximately 4×10^4 weapon-years per year. If the historical cumulative value is taken as an approximation to the expected value, then the overall exposure of the entire inventory leads to a current value of $P_{tot} = 0.06$ per year. This number declines slowly with time assuming the favorable experience to continue. Nevertheless, it is not entirely comforting, since it leads to a 50% expectation of a successful diversion in about 12 years.

The foregoing discussions of the historical record is neutral to the differences in the values of the controlling variables as exhibited in equation 2. For practical decision-making purposes it is necessary to examine at least the order-of-magnitude differences in the controlling variables between the different segments of exposure.

Factors Controlling Weapons Diversion Exposures. It is evident that the preferred target for a would-be diverter, whether national, subnational, or terrorist, would be an actual weapon. Actual weapons represent over 96% of the weapon-years exposure to date, yet there apparently has been no actual diversion, nor even a competently mounted threat of such diversion evident.

Weapons storage locations are protected by vaults and guards. If the statistics of successful breaches of bank vaults applied, one would expect to have seen several dozens of occurrences. Evidently the factor of detection and reaction ($r_{i,t}$) is quite large. The presence of armed guards and barriers of the military installation are certainly significant obstacles. However, under some circumstances such obstacles could be relatively minor to a determined band of attackers, as for example, when weapons or weapons material are being transported by truck, train, or aircraft. The dominant protective factor operating, we may surmise, is the high assurance of detection and reaction, with indefinitely increasing force if necessary.

The probability factor of achieving the successful fabrication of a nuclear device ($Q_{i,t}$) is relatively high for weapons, but not unity as might be supposed. Weapons have defensive features such as separate keys of unique materials, and certain self destruct capabilities, which prevent them from being useful to an adversary who might capture them in a battlefield situation. For the same reason, even a successful peacetime diversion would still require a high degree of technical sophistication, and preferably a variety of detailed technology knowledge accessible only to "insiders", if $Q_{i,t}$ is to attain values as high as 0.1 to 0.5, and given limited periods of time, of the order of several months.

Overseas Exposure of U.S.-Supplied High Enriched Uranium. Approximately 18,000 kilograms of this material have been supplied to countries overseas (1). For various reasons, the United States did not establish a pattern of tracking this material point by point and moment and moment but relies on either bilateral agreements or IAEA accountability and inspection. At a any given time, up to 2,000 kg. of such material is present overseas as raw material (uranium metal, uranium hexafluoride, or uranium oxide) or as material undergoing fabrication processes and including fabricated fresh fuel.

Something in the range of a half of a ton of such material is present at any given time in operating reactors, where it has associated with it the high levels of radioactivity of operating nuclear fuel. By far the largest part of this material exists in spent fuel pools scattered in roughly 100 locations, in 40 countries, with the bulk of it in Western European countries and Japan. Allowing for the elimination of some U-235 by burnup in the fuel, and the relatively small amount which has been returned to the United States for reprocessing, a rough estimate of 6,000 to 10,000 kgs. of highly enriched U-235 remains.

From a diverter's standpoint, the resources, skills and facilities required are substantially higher for radioactive fuel which might be taken from an operating reactor than for unirradiated fuel or raw materials. The highly radioactive fuel from the reactor core has the further disadvantage that attempts to remove or transport it can be detected at long distances by conventional radiation detectors, so that the likelihood of effective detection, reaction and recovery can be very large (provided that such functions are planned and implemented in a given region).

Spent fuel from fuel storage pools still requires substantially more difficult and complex processing than unirradiated fuel or raw material. However, the level of radiation emitted falls off inversely with time (approximately) so that detection at a distance after 1 year and 10 year storage is orders of magnitude less sensitive than for fuel recently removed from an operating reactor.

Medium and High-Powered Test reactors in the United States

Most of these reactors are operated by the Department of Energy and are located at national laboratories or weapons laboratories and associated facilities. In aggregate, these reactors involve similar amounts of material (within factors of 2) to the medium and high-power test reactors overseas. However, the effective exposure is an order of magnitude smaller than for the overseas reactors, since the spent fuel is routinely returned for processing, and returned to locations with military grade levels of protection and reaction forces. There appear to be no plans to convert domestic research and test reactors operated by the Department of Energy to lower enrichments.

Research and Test Reactors - Low Power

Over 50 low-power research and test reactors are operable within the United States, and roughly 30 of them involve some high enriched U-235 fuel. Most of these reactors have "lifetime cores" since the power level and duty cycle will take at least 20 years to reach the physical burn-up limits of the fuel. Many of these reactors are licensed to carry as inventory substantial additional amounts of unirradiated fuel, either as fresh fuel or as spent fuel awaiting shipping and storage. Augmented security procedures brought into effect in 1983 have largely eliminated the inventory of unirradiated fuel (or else provided for its storage at a DOE facility). With these measures, the amount of inventory at a typical university research reactor facility is less than 5 kg. and for some reactors less than 2 kg. A would-be diverter would have to remove and recover the material from at least three reactors to achieve some probability of producing a "high technology" device, and from at least half a dozen research reactors in order to have some chance of producing a "low technology" device. Nevertheless, of NRC has a draft rule pending which would require the conversion of all remaining non-DOE research reactors to low enrichment under 20% U-235 (2).

A decision was reached in the late 1970s that the continued shipment of tonnage quantities of highly enriched of U-235 overseas constituted an undesirable risk, particularly since assurance of low values of $d_{i,t}$, or high values of $r_{i,t}$ could not be assured. Quantites of material $A_{i,t}$ at single locations range from several to many "low technology" nuclear devices. The process of conversion to low enrichment for exports is underway. However, the technical obstacles to producing high performance fuel at 20% enrichment (without substantial redesign of the reactor facility), are delaying implementation of this change to the late 1980s.

The conversion of domestic non-DOE research reactors is being proposed as a risk reduction measure, apparently for two reasons; (1) to further reduce the already small risk that successful diversion simultaneously from a number of reactors might result in a single nuclear device, and (2) to "set a good example" for overseas research and test reactors community (who have objected to the substantial increases in costs and loss of performance and reliability associated with the lower enrichment fuels*).

Measures of Cost Effectiveness of Risk Management Options

Substantial increments in physical security and presumably in detection and recovery forces have been implemented for military stores of weapons and weapons materials in recent months. These actions appear to be in response to the impacts of the terrorist bombings in Lebanon and elsewhere, and a general White House directive to augment physical security measures for facilities of all kinds. This appears to be a cost-effective approach, since nearly all of the people involved are already federal or contractor employees, so the main effect is assure that effective plans and communications are organized.

COST EFFECTIVENESS OF CONVERSION TO LOW ENRICHMENT

The federal costs (mostly R&D) for conversion of overseas reactors are of the order of $30 to $50 millions. By the late 1980's this action will reduce the continuing inventory of high enrichment uranium in reactors and in the production pipeline by more than two tons.

The cost of this improvement to the U.S. is about $20/gram of material removed from service (not counting the procurement and conversion costs incurred overseas).

This strategy avoids increasing the continuing diversion risk exposure from the tonnage of spent fuel in storage pools, but does nothing to decrease it. This remains by far the largest store of weapons-useable U-235 not in U.S. custody. Overseas holders of this material are deterred from returning it to the United States since it costs them more than retaining it in storage pools. (The United States is prohibited by the NNPA of 1978* from expending any funds for receiving, storing, or processing any kind of spent fuel from overseas, but a year-to-year exemption for high enrichment fuel has been decreed).

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*Some overseas research reactor operators, mostly in government facilities, have objected that the conversion of university research reactors is meaningless as a "good example" since the medium and high powered and test reactors operated by the DOE are not affected.

On the current course of events, the cost vs. risk reduction benefits in vogue are shown in Table 2. The U.S. costs committed per gram removed from service (ideally a rough measure of assigned risk-reduction value), are actually in reverse order of the size of risk exposure. The most curious disparity is the effective assignment of a negative value to the dominant residual diversion risk of this type, namely the spent fuel tonnages overseas, which contain several hundred weapon equivalents.

The diversion risk ($d_{i,t}$) refers to the probability of removal of a weapons-usable amount from a given location (see equation 2). The likelihood of theft or diversion would seem obviously smaller in a military facility than in an civilian facility--say at a university. However the risk-controlling factor at a given location is not ($d_{i,t}$) but the entire expression $P_{i,t}$ in Equation 2. The value of $A_{i,t}/M_b$ is much smaller than 1.0 for low power research reactors, while it can take values in excess of several hundred at military locations.

The assumption that diversion risk exposure per kilogram is not widely different, between the different materials (because of the offsetting effects of the factors controlling $P_{i,t}$) enables a semi-quantitative ordering of the rank of diversion risks for the categories shown in Table 1. Taking the historical value to date as the annual expected value $P_{tot} = .06$, the values in the right hand column are derived. On this scale, the conversion of overseas reactors to lower enrichment has appreciable overall value in reducing P_{tot}.

This leaves the spent fuel overseas as the dominant risk other than military. On this scale the small domestic reactor exposure is about two orders of magnitude smaller than the residual risk from spent fuel overseas.

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*Nuclear Nonproliferation Act of 1978.

Reduction in the diversion risk exposure of U-235 in spent fuel overseas has at least equal value, per unit retired, as for small domestic research reactors. If $100 per gram retired from service domestically is a proper valuation, then instead of charging for the return of overseas U-235, the U.S. should be willing to pay for its return. If the values are equated, the U.S. should be willing to pay at least $0.6 Billion for comparable value in risk reduction.

References

(1) "Proposed Rule for Limiting the Use of High-Enriched Uranium (HEU) in Research and Test Reactors" NRC document Federal Register June 30, 1984.

(2) "Obstacles to U.S. Ability to Control and Track Weapons-Grade Uranium Supplied Abroad" U.S. General Accounting Office Report GAO/ID-82-21, August 1982.

TABLE 1. RANKING OF DIVERSION EXPOSURES

	CATEGORY	ESTIMATED VALUE $P_{i,t}$ PER YEAR
I.	WEAPONS MATERIALS AND FACILITIES	.05
II.	LARGE TEST REACTORS USING HEU ABROAD	
	A. Unirradiated fuel materials	.005 *
	B. Irradiated fuel	.005
III.	LARGE TEST REACTORS - DOMESTIC	.0005
IV.	SMALL RESEARCH REACTORS AT UNIVERSITIES	.00005

*Subject to gradual reduction 1985-1990 by displacement with low enriched uranium.

TABLE 2. Relative Cost vs. Risk Reduction Benefit of Current Commitments

Location	Type of Material At Risk	Weapons Equivalents Amounts Per Location	$/gram committed to reduce exposure
Domestic	Fuel for DOE Reactors	Several to Many	~0
Domestic	Fuel for non-DOE Reactors	0.1 to 0.2	> $100 *
Overseas	Future Fuel for Medium and high power Research & Test Reactors	Many	~$20
Overseas	Spent Fuel Containing Highly Enriched U-235	Many dozens	< 0 **

*Based on ref. (1), if promulgated without changes.

**U.S. requires substantial payment to accept the return of such fuel.

Mrs. LLOYD. Thank you very much, Mr. Zebroski.

Something that troubles me in Dr. Bernthal's testimony, he indicated that we do have sufficient quantities of high enriched uranium to make a nuclear explosive device at our universities and you indicate in your testimony that we do not have.

Would you care to elaborate on that further?

Mr. ZEBROSKI. I think, as I heard his testimony, it was not disagreement on that point. If you take the unirradiated fuel, which everyone agrees is the interesting target for diversion, I just shared notes of a later speaker and that total is right now 18 kilograms, but the question is not could you make a bomb with 18 kilograms; the question really is: Are there administrative processes which could make that quantity substantially below 10 kilograms nationally so that, in principle, you'd have to steal all the reactors and still not make a weapon and I think that is administratively feasible. So I think Mr. Bernthal was describing the situation as it now exists. Potentially you could make a weapon, but you could eliminate that situation without conversion to low enrichment by administrative limits on the amount of unradiated material kept in inventory.

Mrs. LLOYD. In other words, you would control it by inventory——

Mr. ZEBROSKI. Yes, with DOE——

Mrs. LLOYD [continuing]. Rather than conversion.

Mr. ZEBROSKI. DOE and NRC have total control——

Mrs. LLOYD. You say that you felt that we would have a loss of our research reactors by conversion if ordered by the NRC. What percent of the research reactors in existence today do you think we would see closed down if we were to enact these regulations?

Mr. ZEBROSKI. I'd prefer to sidestep that. I can make my own personal guess. It's enough to be substantial, but I think the fourth panel will touch on this subject.

Mrs. LLOYD. Well, do you think there's any need to convert to low-enriched fuel?

Mr. ZEBROSKI. I would, in agreement with one point of Commissioner Bernthal, agree that you can make the inherent risks less. I would go along with a long-term objective of converting the reactors that have substantial inventories and inventory handling to lower enrichments, but perhaps in the 40- to 50-percent range. This still makes, to me, weapons—quite a weapon derived from a small inventory of that material totally incredible.

I think you should ask Dr. Mark, who's perhaps the world authority on this——

Mrs. LLOYD. How——

Mr. ZEBROSKI [continuing]. Subject——

Mrs. LLOYD. OK.

Mr. ZEBROSKI. But——

Mrs. LLOYD. I want all of you to give me your input on the panel.

Dr. REMICK. I would like to respond to your——

Mrs. LLOYD. All right, please do.

Dr. REMICK [continuing]. Question. In addition to being a member of ACRS, I'm a former director of a university nonpower reactor and currently am acting vice president for research and graduate studies at the Pennsylvania State University, which is a licensee.

However, it's a licensee of a nonpower reactor which converted back in 1965 to LEU, so I don't have a personal axe to grind, but I'd like to respond to your question of how many reactors would close down.

I would say that if the universities—and this would probably apply to some of the nonuniversity nonpower reactors also—if they're required to pay the full cost of that conversion, including the cost of potential litigation through the public hearing process, I think I would not be going on a limb to say that more than half of the university research reactors would have to close down, just like UCLA did. A few hundred thousand dollars to a university-supported facility like this is considerable.

So it would be my guess that at least half of them——

Mrs. **Lloyd**. You think we should have a further study on the cost of litigation and the other factors involved?

Dr. **Remick**. Yes; as I read the Commission's regulations on this, it's not clear whether—excuse me, let me back off. The Commissioner said that if this did not require a change in technical specifications, then they could see that this could be done readily. I would read, and I'd like my colleagues who follow on the later panel to also interpret—I would think that most nonpower reactor technical specifications would have to be changed by such a conversion because most of the technical specifications specify the type of fuel that you can use.

If you change that fuel, you have to change the technical specifications. As I read the Commission's regulations, it's not clear on whether the Commission would have to require a public hearing. However, it's at their discretion. In the case of UCLA for a completely different reason, they allowed the public hearing. The public hearing went on for 4 years and finally the university threw in the sponge.

It would seem to me that if conversion is going to be mandated from a public-interest standpoint, that what I would suggest is that Congress exempt the NRC from the requirement of a public hearing for this type of conversion. It is not a reactor safety issue; it's a public policy in the interest of limiting diversion that would be the driving force. It seems to me, naively perhaps, that Congress could exempt the NRC from public hearings of this case. This is one of the biggest risks.

I do think that DOE, with proper funding, can fund the conversion, the provision of the fuel and perhaps many other things. The real unknown quantity is potential litigation that could drag out for years and cost many hundreds of thousands of dollars.

Mrs. **Lloyd**. Well, in litigation, do you think the cost is—if it is mandated—should be borne by DOE?

Dr. **Remick**. The cost of the—providing the fuel and the physical requirements and so forth——

Mrs. **Lloyd**. The public hearings and the cost of litigation.

Dr. **Remick**. The hearings—I see it slightly different. I think that the NRC—because, as I read the regulations, it's not mandatory; its discretionary and they're not sure, of course, how the higher courts are going to react if they say there need not be a hearing, but if Congress says that they would exempt the NRC from the need to hold public hearings, then I think that would be overriding and that would remove considerable uncertainty that's there about the risk of public hearings on a conversion process.

I do have to agree with what Commissioner Bernthal said that I think in general nonpower reactors, whether university or not, think it's a long-term worthy objective to convert as much as we can to low-enriched uranium, but it's a question of how expeditiously, at what cost, and who must pay the cost.

I think that's the real question.

Mrs. LLOYD. Thank you.

Mr. Mark?

Mr. MARK. Well, Zebroski volunteered me to comment on something; I wasn't quite certain on what——

Mrs. LLOYD. We've been sitting here waiting to hear from you.

Mr. MARK. I think—if I remember correctly—that Commissioner Bernthal said that there was not enough unirradiated fuel in any single nonpower reactor, research reactor, or university reactor—I've forgotten just what list he had in mind—to make a credible bomb supply for an explosive device, but that there might be if you took both the unirradiated fuel and the fuel from the reactor which had been irradiated.

Mrs. LLOYD. Uh-huh.

Mr. MARK. Then from some reactors, you could get enough. Now, that was my recollection of what he said. It is not inconsistent with what I think Mr. Zebroski has been saying, and I would like to concur on a point which Zebroski made which hasn't been made enough, it seems to me, in our attempts to think through this question, and that is that high-enriched uranium, which gets those—that simple abbreviation HEU, is really a whole area of different materials, all the way from 90 percent U-235 down to 21 percent U-235 and is not a unique substance.

It is possible on paper to imagine that you could make an explosive out of anything in that range, and in fact, it's even possible down to 10 percent. The penalties, however, are quite tremendous. If you cut the enrichment from 90 percent to about 50, you more than double the amount of material that the terrorist has to cope with and the weight of the apparatus he will need to cope with it, the amount he will have to steal and so on. So that 50 percent material, although it's still HEU, is not the same as 90 percent material, and by the time you get down to just about 20, you've got more than 10 times as much material you have to steal and 10 times as much material you will have to move to make an explosive device.

So that there is room for thought along the lines that Zebroski mentioned; that we would make things more proliferation resistant if we approach it rationally, even without going in this blind black and white categorization that we've gotten used to thinking of.

That seems to me a careful analysis of the program would deserve to take into account, at least to look at. It may be hard in an international scene to introduce any changes in the terms or the definitions that are used.

I think it has been said and I guess I would like to say it, since I don't have anything else planned, unless you should come after it, making a bomb is far from as easy as some people have sometimes said. It requires a quite serious, very knowledgeable and determined group to make an explosive device with any probability of having success with it. However, we are dealing here with a very sort of emotional field in which even stealing some uranium, even if it is not enough to make a bomb, even if the fellows who steal it don't have the vaguest intention of doing so or the ability to do so, all they have to do is put it on the nightly news that they plan to do so and we're really up in the air for a very serious thing.

So that, to some extent, one needs to think that reducing the enrichment is not just an easily measurable quantifiable thing—so many dollars it costs, so many dollars it saves. We're dealing with a very touchy and uncontrollable matter and we're dealing with an international scene which is at least as hard to assess quantitatively and a policy in which Congress, I believe, has said on many occasions that we want to get rid of the existence of highly enriched uranium or uranium capable of making explosives.

How do you respond to this? I mention it, not that I have any nice recipes for you.

Mrs. **Lloyd.** Thank you very much.

Mr. Ebersole, you mentioned that you thought that this conversion should be made in a gradually—gradual and orderly manner as funds become available. Do you—do you mean that you think that this conversion is necessary or do you think that it's inevitable?

Mr. **Ebersole.** Do I think that it's necessary?

Mrs. **Lloyd.** If I understood you, you said that you thought the conversion should be made in a gradual——

Mr. **Ebersole.** Yes, right.

Mrs. **Lloyd.** [continuing]. Orderly manner.

Mr. **Ebersole.** I don't think that it's necessary. I think a gradual elimination of high-enriched uranium would be a good thing on general principles. I don't see it necessary in the context that we jump to this sort of thing, crash into it.

Mrs. **Lloyd.** Well, I know that you believe that the owners of research and test reactors should be given the option of converting or——

Mr. **Ebersole.** Yes.

Mrs. **Lloyd.** [continuing]. Or meeting appropriate security requirements. Do you believe that our present security requirements are inadequate?

Mr. **Ebersole.** The best thing I can say about that is I have yet to find what I call a standard or generic or typical or universal set of criterion standards for how we treat our university reactors. I need to see what that system is. I haven't found it. I'm rather suspicious that it is nonexistent, so I can't tell you without knowing what the security requirements are and finding some more or less generic or standard basis——

Mrs. **Lloyd.** Do you feel that we should do further study——

Mr. **Ebersole.** Yes.

Mrs. **Lloyd.** [continuing]. On what our security requirements are—what is——

Mr. **Ebersole.** That's correct. I need to know what the security systems are before I can speak to them.

I'd like to also say that there're two aspects of this. The security aspects in relations to terrorism for the purpose of stealing uranium to make bombs, I suspect, are rather adequate. However, this matter of security aspects in creating public turmoil using any kind of devices to upset given research reactors probably will produce as large a public reaction as though something really significant has taken place.

The media, of course, always magnifies these sorts of things a thousandfold and aspects of real importance.

Mrs. **Lloyd**. You think universities do need to do a better job of educating the public?

Mr. **Ebersole**. I think—well, first of all, we need to look at just how well we are protecting against this sort of thing and then, of course, I think everybody needs to educate the public on the real versus the speculative aspects of radiation hazards.

Mrs. **Lloyd**. Thank you very much. I'm sure the other members of this committee who are unable to be with us today will have further questions for all of you and all our panelists. We're very happy that the chairman of our full committee, the Honorable Don Fuqua, is with us now and—do you have any questions?

Mr. **Fuqua**. No.

Mrs. **Lloyd**. Thank you very much for your testimony. You're certainly excellent witnesses and we appreciate your appearance today.

Mr. **Ebersole**. Thank you.

Mrs. **Lloyd**. The chairman of our full committee, Mr. Fuqua, will now take over the Chair. We welcome you, Mr. Fuqua.

Mr. **Fuqua** [presiding]. Our next panel of witnesses from the various agencies will be Mr. Carlton Stoiber, Director of the Office of Export and Import Control of the Department of State; and also with Dr. Armando Travelli, Manager of Reduced Enrichment for Research and Test Reactor Program with the Argonne National Laboratory; and Jim Kane, Deputy Director of the Office of Energy Research in the Department of Energy.

Mr. Stoiber, we'd be pleased to hear from you at this time.

STATEMENT OF CARLTON R. STOIBER, DIRECTOR, OFFICE OF EXPORT AND IMPORT CONTROL, BUREAU OF OCEANS AND INTERNATIONAL AND SCIENTIFIC AFFAIRS, U.S. DEPARTMENT OF STATE

Mr. **Stoiber**. Thank you, Mr. Chairman.

I am pleased to be here today to present the State Department's views on the foreign policy aspects of the NRC's proposed rule for conversion of domestic research reactors to low-enriched uranium fuel. In particular, I will attempt to address the relationship between such conversions and the administration's nuclear nonproliferation goals.

The office that I head is responsible for coordinating executive branch views for the export licensing process in the nuclear area. We also work closely with the Department of Energy in the development of the RERTR Program, or the Reduced Enrichment for Research and Test Reactor Program. Since 1978, similar programs for reduced enrichment fuels have also been established in a number of countries, including France, the Federal Republic of

Germany, Japan, Canada, and the United Kingdom. Programs for studying reactor conversions are in progress in 19 other countries.

The International Atomic Energy Agency has established, also, a small program to coordinate and promote educational activities related to the overall reduced enrichment effort with a particular emphasis on developing countries. The cooperation among participating governments in this program has really been quite outstanding. The technical program to develop and demonstrate high-density low-enriched fuels for research reactors is proceeding very well.

Aluminide, oxide and silicide plate-type fuels have been developed by DOE with fabrication capabilities demonstrated already by several commercial manufacturers, including NUKEM, in the Federal Republic of Germany, CERCA, in France, and Babcock & Wilcox in the United States.

In the United States, zirconium hydride rod-type fuels have been developed by GA Technologies and Babcock & Wilcox has also established a commercial capability to manufacture plate-type fuel elements.

Canada, Argentina, Denmark, the United Kingdom, Japan, and the Soviet Union are also developing and evaluating low-enriched fuels. An important aspect of the U.S. Program is Argonne's involvement with the operators of foreign research reactors through the development and demonstration phase to examine the possibility of timely conversion to the use of low-enrichment fuels and also with operators of U.S. reactors in testing and evaluating the technology.

Joint studies on conversion feasibility are ongoing between Argonne and reactor operators in 12 countries. Also, 15 countries, in addition to the United States, are testing or will test in the near future prototype low-enriched uranium fuel elements in their reactors.

The international meetings, attended by some 50 representatives of over 17 countries, are sponsored annually by the IAEA, the United States and other host countries for exchange of information in this field.

The seventh meeting in this series of annual meetings will be taking place at Argonne National Laboratories in about 3 weeks. We expect approximately 20 nations to be in attendance.

As you have already heard, this program is still largely in the testing phase. Only two reactors in the non-Communist world actually have a full replacement core of low-enriched fuel and have been licensed to use it. These are the Osiris reactor in France and the Ford nuclear reactor here in the United States. Further tests of LEU with high uranium density, including a full-core demonstration with silicide fuel, are required.

The availability of reprocessing services for silicide and other LEU fuels will be a very important issue for LEU conversions and needs to be resolved. For example, in the major user countries, license amendments will not be issued to reactor operators for use of new fuel alternatives unless there is documentary evidence that the reactor operator can dispose of the spent LEU fuel outside the host nation, as has been done to date by returning spent high-enriched fuels to the United States for receipt and settlement.

Credit for recovered uranium is an important economic consideration for the reactor operator because half of the original fissile material remains in the spent fuel. Experiments on reprocessing advanced LEU fuels within DOE facilities have been completed successfully at Savannah River and DOE is currently assessing the overall LEU reprocessing issue.

This testing phase needs to continue and most of the new low-enriched fuels will not be ready for commercial applications until the 1987 to 1989 timeframe. During that period, we should see the new LEU fuels being accepted routinely as a substitute for the current HEU reloads—the ultimate goal of the program.

This brings me, Mr. Chairman, to an important characteristic of the RERTR Program that I mentioned earlier, but which merits further elaboration because it has been a critical factor in the development and testing phases of the program. This is the spirit of cooperation that has prevailed throughout the course of the program.

It is most important that this cooperative spirit be maintained as we approach the reactor conversion stage. A number of factors have fostered this cooperative atmosphere, not the least of which has been the outstanding effort by the Argonne Program managers, scientists and technicians.

Another key contributing factor has been the commitment of the United States to continue as a reliable and predictable supplier of high enriched uranium during the period prior to conversion to the use of LEU. We have pursued a system of voluntary cooperation without arbitrary deadlines.

Our processing of HEU license applications has been expedited over the last 4 years. All of our nuclear trading partners which meet the stringent requirements of the Non-Proliferation Act and its implementing regulations have received adequate and timely supplies of these fuels. This positive approach has been implemented through a rigorous interagency review process which culminates in licensing by the independent Nuclear Regulatory Commission.

We are very anxious to continue this successful approach. In return, we expect continued cooperation by foreign participants on conversion studies and timely conversion when that is feasible.

With respect to United States high-enriched uranium export policy in general, there is unanimous agreement among foreign governments that reduced trade flows in HEU could help to reduce the risks of nuclear proliferation, and I might parenthetically add here, Mr. Chairman, that when we talk of proliferation, we really are talking about two different things. Here in the United States—and the conversation earlier has emphasized the terrorist threat, that is, the diversion by a group of subnational individuals who want to either acquire a weapon or make some sort of political demonstration, but on the international level, we speak of proliferation, we mean the diversion of materials by a national government that might be bent on developing its own nuclear weapons capability.

So I think we have to keep that in mind as we look at the international, as opposed to the domestic, dimension of this problem.

However, the support of other nations for reducing commerce in HEU is conditioned by the obvious necessity that the new fuel should not significantly affect the safety, performance, licensability, and economics of the research reactors. These are, after all, important national, scientific, and technological assets.

Mr. FUQUA. Mr. Stoiber, pardon me a moment. We have a vote and then we're going to have to take a brief recess while I run and vote and we'll be right back and get started.

I apologize for——

Mr. STOIBER. Quite all right.

Mr. FUQUA [continuing]. Interrupting you, but that's part of the life around here.

Mr. STOIBER. That's right.

[Recess.]

Mr. YOUNG. [presiding]. I'm Bob Young; I just lost my pen.

Mr. STOIBER. I've got an extra here.

Mr. YOUNG. No, no, you know how hard they are. I've had this thing about 10 months. Can't remember—I'm glad I'm not running any of these scientific programs. I can't keep my hand on my pen. [Laughter.]

Would you like to proceed, sir?

Mr. STOIBER. Thank you very much, Mr. Chairman.

I had reviewed in a brief fashion some of the international activities that have been proceeding in a cooperative mode between, especially Argonne National Laboratories and other parallel programs abroad in developing reduced-enrichment fuels for test reactors.

I'd like to point out that the concerns and purposes behind our program abroad are, of course, linked to our overall nonproliferation efforts and that this effort will continue, whatever the decision may be with respect to the conversion in the domestic program.

As the period for actual conversion approaches, a few foreign reactor operators have expressed an interest in whether the United States is applying the same guidelines domestically and have asked what steps we are taking to convert domestic research reactors. The actions of the NRC on this matter, therefore, can be expected to have some marginal effect on our future negotiations with foreign reactor operators on the need and timing for converting their own reactors.

In considering measures which will encourage conversion of foreign research reactors, our international experience with RERTR participants has underscored the importance that we be sensitive to licensing and funding issues. U.S. conversion of domestic research reactors to low-enriched fuels is just one of many factors which, in our judgment, will be important for shaping the attitudes of foreign participants in this program.

Among the other considerations, I might list a few:

First, and I think most importantly, the establishment of safe and reliable low-enriched fuels which are commercially available will be key.

Second, the specific reactor geometry and mission of the particular facility being converted will also be important.

Third, the economics of conversion, a matter which has several aspects, including the cost of altering the reactor systems, the incremental cost of new fuels, the incremental cost of revising research experiments or tests using the new fuels and the cost of obtaining an amended operating license, if that proves necessary, will also be important.

Fourth, the regulatory steps which must be taken to relicense or approve operation of a converted facility from a health, safety and environmental perspective.

Fifth, the availability of reprocessing services or back end of the fuel cycle solutions for new fuels is another key factor.

Sixth, whether other nations, including close neighbors, will also be converting their facilities.

Seventh, the perception of other governments that the use of low-enriched fuel is in their best interests from a physical security viewpoint, as we have been talking about earlier, a reduced target for terrorism.

Eighth, the justifiability of high-enriched uranium for operating reactors until the LEU fuels are ready for the conversion process.

This really concludes my prepared remarks and I would be happy to respond to any questions the committee may have.

[The prepared statement of Mr. Stoiber follows:]

PREPARED STATEMENT OF CARLTON R. STOIBER, DIRECTOR, OFFICE OF NUCLEAR EXPORT CONTROL, U.S. DEPARTMENT OF STATE

Madam Chairman

I am Carlton Stoiber, Director, Office of Nuclear Export Control, Department of State. I am pleased to be here today to present the State Department's views on the foreign policy aspects of the Nuclear Regulatory Commission's proposed rule for conversion of domestic research reactors to low enriched uranium. In particular, I will address the relationship between such conversions and the Administration's nuclear non-proliferation goals.

The Office of Nuclear Export Control is responsible for making recommendations to the Nuclear Regulatory Commission for the State Department on various export license applications involving highly enriched uranium (HEU). Related to this, we are also responsible for working with the Department of Energy on the Reduced Enrichment for Research and Test Reactor (RERTR) program, a DOE program oriented toward reducing HEU exports.

The RERTR program was started in 1978 to support a U.S. initiative to reduce the proliferation potential and the threat of nuclear terrorism associated with international commerce in highly enriched uranium. The program goal is to develop the technology needed for conversion of research and test reactors to the use of low enriched fuels (at levels of less than 20 percent). Most of the work is carried on at the Argonne National Laboratory under DOE's aegis. Since 1978, similar programs for development of reduced enrichment fuel have also been established in a number of countries including France, the FRG, Japan, Canada, and the United Kingdom. Programs for studying reactor conversions are in progress in 19 other countries. The International Atomic Energy Agency (IAEA) has established a small program, whose purpose is to coordinate and promote educational activities related to the overall reduced enrichment effort, particularly for developing countries.

Cooperation among participating governments has been outstanding. The technical program to develop and demonstrate high density low-enriched fuels for research reactors is going very well. Aluminide, oxide, and silicide plate-type fuels have been developed by DOE with fabrication capabilities demonstrated by the commercial manufacturers NUKEM, Federal Republic of Germany, CERCA, France and Babcock & Wilcox in the U.S. In the United States zirconium hydride rod-type fuels have been developed by GA Technologies, and Babcock & Wilcox has established a commercial capability to manufacture plate-type fuel elements. Canada, Argentina, Denmark, the U.K., Japan, and the USSR are also developing and evaluating LEU fuels technology. The development of high uranium density, 20% enriched silicide fuel may permit most U.S.-supplied foreign research and test reactors to convert to such fuel, without a change in the geometry of the fuel elements, and without significant penalty in test capability.

An important aspect of the U.S. RERTR program is Argonne's involvement with operators of foreign research reactors through the development and demonstration phase to examine the possibility of timely conversion to use of lower enrichment fuels and with operators of U.S. reactors in testing and evaluating the technology. A whole-core demonstration in the Ford Nuclear Reactor at the University of Michigan is nearly complete and a second whole-core demonstration with high density silicide fuel is being planned in DOE's ORR reactor at Oak Ridge. Joint studies on conversion feasibility are on-going between Argonne and reactor operators in Austria, Japan, Romania, Sweden, Netherlands, Argentina, Australia, Chile, Turkey, Greece, U.K., and Denmark.

Also, the following countries are testing, or will test in the near future, prototype LEU fuel elements in their reactors: Argentina, Austria, Brazil, Canada, Denmark, France, the Federal Republic of Germany, Greece, Japan, United Kingdom, Netherlands, Romania, Sweden, Switzerland, Turkey and the United States.

International meetings attended by some 50 representatives of over 17 countries are sponsored annually by the IAEA, the U.S., and other host countries, for information exchange on the status of R&D within the RERTR and related programs, and on research reactor operation and use. The most recent was near Tokyo in October 1983.

The program is still largely in the testing phase. Only two reactors in the non-communist world actually have a full replacement core of low enriched fuel and have been licensed to use it. These are the Osiris reactor in France and the Ford Nuclear Reactor in the United States. Further tests of LEU with high uranium density, including a full-core demonstration with silicide fuel, are required. In addition, safety analyses are required and related licensing issues need to be resolved before conversion candidates can plan to use LEU fuels.

The availability of reprocessing service for silicide and other LEU fuel, a very important issue for LEU conversions, also needs to be resolved. For example, in the major user countries, license amendment will not be issued to reactor operators for use of new fuel alternatives unless there is documentary evidence that the reactor operator can dispose of the spent LEU fuel outside the host nation, as has been done to date by returning spent HEU fuels to the U.S. for "--receipt and settlement--." Credit for recovered uranium is an important economic consideration for the reactor operator since half of the original fissile material remains in the spent fuel. Experiments on reprocessing advanced LEU fuels within DOE facilities have been completed successfully at Savannah River, and DOE is currently assessing the overall LEU reprocessing issue.

The testing phase needs to continue and most of the new low enriched fuels will not be ready for commercial applications until the 1987-89 time frame. During that period, we should see the new LEU fuels being accepted routinely as a substitute for the current HEU reloads--the ultimate goal of the program.

This brings me to an important characteristic of the RERTR program that I mentioned a few minutes ago but which merits further elaboration because I believe it has been a critical factor in the development and testing phases of the program. This is the spirit of willing cooperation that has prevailed throughout the course of the program. I believe that it is most important that this cooperative spirit be maintained as we approach the reactor conversion stage. A number of factors have fostered this cooperative atmosphere, not the least of which has been the outstanding efforts of the Argonne program managers, scientists and technicians. Another key contributing factor has been the commitment of the United States to be a reliable supplier of HEU in the period prior to conversion to use of LEU. We have pursued a system of voluntary cooperation without arbitrary deadlines. Our processing of HEU license applications has been speeded up over the last four years. All of the trading partners to whom we can export HEU under the Nuclear Non-Proliferation Act regulations have obtained adequate and timely supplies. With the cooperation of the NRC, we trust, we will continue this approach. In return, we expect continued cooperation on conversion studies, and timely conversion when feasible.

With respect to U.S. HEU export policy in general, there is unanimous agreement among foreign governments and programs that reduced trade flows in HEU could help reduce the risks of nuclear proliferation. However, their support for reducing commerce in HEU is conditioned by the obvious necessity that the new fuel should not significantly affect the safety, performance, licensability and economics of the research reactors. With adequate and continued U.S. commitment to meet fuel development and demonstration schedules, including full-core testing, resolution of the LEU reprocessing issue, and continued international participation, and with no undue delay in licensing procedures, the RERTR program should allow for conversion of most research reactors to use of LEU fuel by the end of this decade. The concerns and purposes behind our program abroad, of course, are linked to our overall non-proliferation efforts, and this effort will continue whatever the decision may be in respect to the domestic program.

As the period for actual conversion approaches, a few foreign reactor operators have expressed an interest in whether the U.S. is applying the same guidelines domestically, and have asked what steps the U.S. is taking to convert domestic research reactors. The actions of the NRC on this matter can be expected to have some marginal effect on our future negotiations with foreign reactor operators on the need and timing for converting their reactors.

In considering measures which will encourage conversion of research reactors, our international experience with RERTR participants has underscored the importance of being sensitive to licensing and funding issues.

U.S. conversion of domestic research reactors to low enriched fuels is just one of many factors which, in our judgment, is important for shaping the attitudes of foreign participants in the RERTR program toward conversion of research reactors. Among the other considerations are:

(1) the establishment of safe (the most important factor) and viable LEU fuels and its commercial availability;

(2) the specific reactor geometry and mission of the particular facility being converted (e.g., whether conversion would require major or minor fuel or core reconfigurations);

(3) the economics of conversion--a matter which actually has several aspects, including the cost of altering the reactor systems, the incremental cost of new fuels, the incremental cost of revising research experiments or tests

using the new fuels, and the costs of obtaining an amended operating license, if that should prove necessary;

(4) the regulatory steps which must be taken to re-license or approve operation of a converted facility from the health, safety and environmental perspective;

(5) the availability of reprocessing services or back-end of the fuel cycle solutions for new fuels (This is likely to be a very key factor);

(6) whether other nations, including close neighbors, will also be converting their facilities, concurrently;

(7) the perception of other governments that use of LEU fuel is in their best interests from a physical security viewpoint (i.e., less attractive target and because it is less costly and difficult to protect LEU than to protect weapons-usable material); and

(8) the justifiable availability of HEU for operating reactors until the LEU fuels are ready for the conversion process.

This concludes my prepared remarks. I will be happy to answer your questions at the appropriate time.

Mr. YOUNG. Thank you very much, Mr. Stoiber.

Dr. Kane, the Deputy Director of the Office of Energy Research, U.S. Department of Energy. Dr. Kane, without objection, your statement will be made a part of the record, sir, and you can summarize in any manner that you like.

STATEMENT OF DR. JAMES S. KANE, DEPUTY DIRECTOR, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY

Dr. KANE. Thank you. Mr. Chairman. I will do just that. I will try to comment and summarize the Department of Energy's position.

I'll do that in really two steps. First, I'd like to describe the DOE involvement in this whole subject of university research reactors and this reduced enrichment program.

Second, I would like to make comments on the proposed NRC rule. As to the involvement, there are three organizations in the DOE that are involved in this program. The first is the Assistant Secretary for Nuclear Energy, and he has the responsibility for the research, development, and demonstration of the low-enrichment fuels.

Now, I understand that several previous witnesses have said that this program technically is going very well. I will say no more on it because the next witness is in charge of that technical program and I imagine he'll give you the details of how progress is coming.

The second organization in the Department of Energy that is involved is the Defense Programs, under the Assistant Secretary for Defense Programs. They have the capability for chemically reprocessing the spent fuels and they are the ones who will ultimately do it. They have been involved in seeing how the new fuels will affect their reprocessing streams and my understanding is that there are no insuperable technical obstacles to accepting the low-enrichment fuel and that the Department will publish a statement, probably this coming December, on the conditions of acceptance and reprocessing. We accept the fuels back; we give credit for the unburned uranium and then it's our decision—and by "ours," I mean the Defense Programs decision, on whether to reprocess or store for reprocessing at a later date.

The third organization within the Department of Energy that's involved is the one I represent personally and that's Energy Research. Our two, rather joint—we have in the past, from the days it was the Atomic Energy Commission up to the present, been a fuel supplier for the campus reactors. By that, I mean, we own the fuel, but we loan it to the universities. We supply the fabricated fuel elements to the universities. We do not in general supply transportation to and from, but we furnish the fuel essentially free of charge.

Another thing we have that your committee asked us to do was a comprehensive cost estimate and it's due to you December 31. Now, I don't mean to imply that this is going to be a reactor-by-reactor statement of how much this conversion might cost. It's more of a generic study to try to flesh out the kinds of costs that will be incurred. I guess, parenthetically, I ought to add that I don't believe there will be a discussion of possible litigation costs, a subject that was brought up previously. I doubt very much if we will try to get a handle on how much that could be.

The DOE has in the past supported these campus research reactors and I think it's only fair to spend a minute or two just telling you why and do we expect to continue. The answer: We do expect to continue and the reason why is because these are an almost—they're an irreplaceable source of training for the people that are going to manage and control the nuclear operations of this country in the next generation.

We must train these people and the best way to train people, like flying an airplane, is to start in a trainer and these research reactors, in many cases, are our training capability. They give the universities opportunities to supply hands-on training to people interested in becoming part of the nuclear enterprise, and in spite of what you might think, the nuclear enterprise in the United States is far from dead. Even if we don't build any more reactors beyond those currently on the books, there is going to be a need for skilled manpower to run them, to engage in nuclear waste disposal and engage in a variety of other nuclear enterprises as far ahead as we can see.

So I think this is a firm commitment by the DOE. We're in this program because we believe it's an essential part of the educational process and we intend to stick with it. So we will, I believe, be suppliers of the fuel. If the decision is made that it be low-enriched fuel, we'll be the suppliers of the low-enriched fuel.

I believe that about summarizes my comments on our involvement. Of course, I'll be glad to answer questions.

Now let me briefly summarize our comments on the proposed rule, and I guess I should point out that the official comments to the NRC will be in a letter from our Secretary to the NRC, but I believe it's highly likely that what I'm about to say will be a part of that, if not exactly what the Secretary will say.

First, I point out that we support the goals of this program. Every previous witness has pointed out that it is a desirable goal to reduce the amount of attractive, highly enriched material in circulation in the United States or the world—better yet, the world. So it becomes a situation of cost benefits. What is it worth to us to reduce this flow and, of course, that means we ought to take the easy targets first. And we do support the conversion of certain steps toward this conversion.

One of the first things we've already done, or are in the process of doing, and that is to offer the universities places to store unirradiated fuel. Now, as all the previous witnesses have agreed, the most attractive target is unirradiated highly enriched fuel, and we'll make every effort we can to reduce the on-campus inventory of that unirradiated highly enriched fuel.

And the amount out there right today, which has been a subject of previous witnesses' discussion, really isn't very large and we can reduce it even further and we will make it such that I believe that you'd have to almost say you would rob every one of the 45 reactors, or at least all 21 of the higher powered reactors, before you would have enough to even consider making one explosive device. I don't want to get into how much uranium it takes to make an explosive device; it's not my business to say that, but that's the first step the DOE is going to take, to try to make it possible to reduce the on-campus inventory.

The second thing is we will assist in converting. We particularly think we ought to start, if this rule—if it covers any of the reactors, if it's decided to impose this conversion, we ought to start with the reactors that take annual refueling, and there are seven of these. They are high-powered reactors; they take annual refueling. Perhaps not all of them will be technically able to be converted. I don't want to take a position on that; that's something—we'll come to a definite conclusion on. But we think it's a reasonable thing to convert these plate-type high-powered reactors under the kind of "if" conditions—if we phase in the low-enriched uranium, after having burned up existing supplies of high-enriched uranium, and if studies show no significant cost or performance penalty will result—now a previous witness—I think Dr. Bernthal—said essentially the same thing and the Chairman at that time said, "What do you mean by a significant performance or cost penalty," and again, I think the NRC will be the arbiter of that. It's not for me to try to sit here and define what "significant" means.

In my mind, you know, we ought to question this conversion if it affects the reactors such as to seriously compromise what we expect them to do in the first place.

We do not support the conversion of reactors that have a lifetime supply of fuel, and this includes four of the so-called TRIGA-type reactors that have essentially a lifetime supply of fuel. And the reason is we think if we keep the inventory of unburned fuel small, we do not think that the relatively small amounts of exposed—and by that, I mean highly radiating, highly radioactive fuels—is a credible target. It certainly isn't an attractive target, so we do not believe it's cost effective to remove and replace this highly radioactive fuel. It will be costly to take out; it will be costly to transport and we're going to replace it with low-enrichment fuel. We just plain don't believe that's cost beneficial.

So that's the DOE opinion. We support conversion of some, if it's proven that it can be done in a reasonable way. We do not support the conversion of those with lifetime inventories of fuel.

Finally, and this subject has been mentioned so much. I think I'll just mention it once and get off of it, and that is, we're concerned about the procedural requirements that'll be invoked to do this. We urge the NRC to do like the sign on the Maryland highway says: "Drive Gently." We think this has to be done very gently because it opens all sorts of problems. They're not power reactors. They have limited resources—the universities do—and we think that, as a previous witness says, if the requirements are too high, some of the universities will just say it isn't worth the gamble. They won't do it.

And by the way, I might point out that at the current time, the Department of Energy has no provision to pay for the conversion as far as the studies that must be made. We're willing to pay for the new fuel elements if conversion takes place, but the safety and other analysis, we are not prepared to.

That concludes my statement. I'll be pleased to answer any questions you might have.

[The prepared statement of Dr. Kane follows:]

PREPARED STATEMENT OF DR. JAMES S. KANE, DEPUTY DIRECTOR, OFFICE OF ENERGY RESEARCH, U.S. DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittees:

It is a pleasure to appear before you today to review the Department's goals for the University Reactor Fuel Assistance Program and present our position on the proposed NRC rule for the conversion of university research reactors to the use of low-enriched uranium. I will cover in my testimony the origin of the university reactor program, the role these reactors play in science and engineering education, and our response to the proposed refueling of these reactors with low-enriched uranium (LEU).

By way of background, the University Reactor Fuel Assistance Program was initiated by the Atomic Energy Commission under authority of the Atomic Energy Act of 1954, Section 31. Following World War II, the science and technological base for nuclear research essentially resided at a few contractor and national laboratory facilities. It was clear, however, that the university community had to be involved if progress were to be made in developing the many potential applications of nuclear energy. During the next decade, the Atomic Energy Commission encouraged and supported the establishment of a wide range of university-based nuclear and radiation safety training programs in reactor and radioisotope technology, and in biology and medicine. Graduate research fellowships were established in nuclear science and engineering, health physics and industrial medicine. Grants were provided to universities to build or purchase training and research reactors. Research equipment and instrumentation were also provided to universities for nuclear research and teaching the fundamentals of radioactive materials.

The goal in establishing and supporting these university facilities was not only to train future nuclear scientists and engineers in the design and operation of nuclear reactors but also to provide the research tools essential for the application of nuclear and radiation technology to medicine, agriculture, materials and the geosciences. These same needs continue today.

At the present time there are 46 university research and training reactors, ranging in power levels from zero to 10 megawatts. The three general classes are: 1) those that use the Materials Test Reactor (MTR), plate-type fuel; 2) those that use the TRIGA cylindrical fuel rod and 3) the seven small facilities that use a homogeneous type uranium oxide fuel either in polyethylene discs or solution form. (See Table I for selected characteristics of these facilities.)

Currently, there are 25 university nuclear engineering departments offering BS, MS or PhD programs and 37 other nuclear engineering programs combined with other departments. In 1983 these programs produced 674 BS degrees, about 1% of the total BS engineering degrees that year. There were more than 1500 graduate students enrolled in nuclear engineering programs in the fall of 1983, including some 250 who were working in industry or government jobs and taking graduate degree programs part-time. Recent manpower studies forecast continuing increased demand by industry for nuclear engineering graduates, particularly for operational and quality assurance positions. We believe that continued direct access by students to university-based nuclear research reactors is very important in their preparation for future professional careers in nuclear R&D and operations.

Many university scientists and engineers use university research and training reactors and their associated analytical facilities. As a source of thermal neutrons for a wide variety of research, a reactor is still one of the more effective research tools available. The range of research conducted on university reactors was illustrated in the results of a recent International Symposium hosted by the MIT Nuclear Reactor Laboratory. This Symposium on the Use and Development of Low and Medium Flux Research Reactors, brought together over 200 participants from research reactor centers in twenty-one different countries. The discussions in this Symposium clearly underlined the broad range of applications of research reactors on a worldwide basis and the continuing interest in the use of these research tools.

The main use of the smaller reactors is for instruction, usually for classes in nuclear engineering and radiation protection, at both the graduate and undergraduate levels to demonstrate various principles of nuclear reactor physics. Many demonstrations and experiments are also carried out for undergraduate students in physics, chemistry and biology classes. A number of universities also use their facility to provide basic training for reactor operators and operations managers for utilities installing power reactors. This is possible because basic neutron behavior is the same in small reactors as it is in large power reactors. These services would not be as easily and economically provided if university reactors were not available.

Regarding the fuel used in university reactors, currently, there are only two fabricators of research reactor fuel in the United States. G. A. Technologies in San Diego, Ca. produces a rod-type uranium-zirconium/hydride fuel for the TRIGA reactors. Babcock and Wilcox in Lynchburg, Va. produces the MTR plate type fuels for reactors using MTR-type assemblies. Of the seventeen university TRIGA reactors, thirteen use a 20% enriched uranium fuel and four use a 70% enriched fuel developed in the late sixties by General Atomics in the fuel-life-improvement program (FLIP) to reduce the costs of fuel procurement and shipment. Each of these four facilities has an estimated fuel supply of about twenty years.

This fuel is loaned by DOE to the universities with title remaining with the government. Our support covers the fabrication costs of the fuel elements and shipment to the universities. Spent fuel is returned to DOE for reprocessing or storage. The MTR plate fuel is sent to Savannah River and the TRIGA fuel to the Idaho processing facility. It should be noted that due to its chemical composition and cladding material, the TRIGA fuel must be reprocessed separately from the plate type fuel.

We also support a small activity called "Reactor Sharing", which assists universities with the additional costs incurred when they make their reactor and laboratory facilities available to scientists and students from other colleges and universities for research and training. Seventeen sharing grants averaging $15,735 were made in FY-1984. For the last complete grant year 173 schools, involving 1900 students and 198 faculty, participated in the program. Such a program makes more efficient use of the existing reactor facilities, reduces the need for new reactors and allows faculty at colleges and universities without reactors to both offer courses of study in the nuclear sciences and to conduct research.

Let me now turn to the Department's position on the proposed NRC rule calling for all licensed research and training reactors using high enriched fuel to convert to low enriched fuel. We understand that the primary reason for NRC's proposed action is to discourage nuclear weapons proliferation by encouraging foreign research reactors to change to the use of LEU. Since our objective is primarily to set an example for other countries, then careful consideration must be given to the cost-benefit aspects and the overall effect such a requirement will have upon the universities.

Last December, in testimony before the Nuclear Regulatory Commission, the Department supported the conversion to LEU for university reactors refueled on an annual basis, provided that acceptable LEU fuel was available. We also volunteered to store unirradiated HEU fuel at secure DOE sites, if needed, to further reduce on-campus inventory. Our support of these conversion activities assumed that the LEU fuel will be phased in as existing fuels are used up and that conversion would not result in any significant economic or technical penalty to the individual university.

Our position was based in part on the fact that if the small amount of unirradiated fuel a reactor might have is adequately stored, either on campus or at a DOE facility, the diversion of unirradiated fuel ceases to be an issue. We have never considered the diversion of irradiated fuel to be a credible issue. The difficulties in surreptitiously handling highly radioactive elements plus the technical and financial resources needed to separate the uranium in sufficient amount for a nuclear device make such a threat, if any, extremely remote.

Our main disagreement with the proposed NRC rule centers on its treatment of reactors that have essentially a life time supply of fuel. It is worth noting that the U.S. government is not seeking the conversion to LEU of foreign reactors with lifetime cores. With the exception of the four, one-megawatt TRIGA reactors which use a different type of fuel, these are small, low powered reactors with in-core inventories of less than five kilograms of U-235. We believe that theft or diversion of fuel from these small facilities is unattractive, and therefore extremely improbable. In fact, the total amount of HEU currently in storage at all of these low power reactors is less than 15 kg's.

If conversion of all U.S. university reactors is mandated, some are almost certain to cease operation. For negligible benefit, we will have lost a valuable nuclear training and research capability.

We are further concerned with the effect relicensing may have on a university. It should be pointed out that the NRC's licensing criteria contained in (Part 50, Title 10 Code of Federal Regulations) are primarily for large power reactors operated by utilities. These same procedures are used in various modified forms for the low power research and training reactors that differ widely in design, operation and use. We suggest that NRC look closely at their licensing procedures for these low power reactors to see what revisions are possible to lessen the risk to universities faced with relicensing.

In summary, we recommend that the small research reactors with a life-time fuel supply, and the four TRIGA reactors with FLIP type fuel, be exempted from the proposed NRC rule and that conversion of other HEU fueled reactors proceed only after existing stocks of HEU fuel elements are used, and when conversion can be done without a serious technical or economic penalty.

The Department of Energy strongly supports U.S. initiatives to prevent nuclear weapons proliferation. However, we seriously question whether broadly imposing LEU conversion on domestic university reactors (which contain only small amounts of special nuclear materials) would have any positive and impact on the proliferation issue.

Mr. Chairman, this concludes my prepared testimony and I will be happy to answer any questions you might have.

UNIVERSITY RESEARCH AND TRAINING REACTOR

UNIVERSITY	REACTOR TYPE	KW POWER	ENRICH-MENT	KG IN-CORE	KG STORED* UNIRRAD	KG STORED* IRRAD
Plate Fueled Reactors						
University of Missouri-Col	PWR, Open pool, LW Mod & Cooled	10000.00	93	5.40	1.55	35.00
Georgia Institute of Technology	Tank, HW Moderated & Cooled	5000.00	93	3.01	4.90	.12
Massachusetts Institute of Technology	Tank, LW Mod. HW Reflector	4900.00	93	8.80	0.96	18.00
University of Virginia	Pool, LW Moderated	2000.00	93	3.23	4.38	4.7
Rhode Island Nuclear Science Center	Pool, LW Moderated	2000.00	93	3.60	0.25	4.2
University of Lowell	Pool, LW Mod. Graphite Refl.	1000.00	93	3.30	0.00	.75
University of Michigan	Pool, LW Moderated	2000.00	20	6.35	0.00	0
University of Missouri-Rol	Pool, LW Moderated	200.00	89	2.87	0.00	1.4
Virginia Polytechnic Institute	Argonaut, LW Mod. Graphite Refl.	100.00	90	3.11	1.20	3.4
University of California, L.A.[1]	Argonaut, LW Mod. closed 8/84	100.00	93	3.56	0.00	0
University of Washington	Argonaut, LW Mod. Graphite Refl.	100.00	93	3.43	0.61	.21
University of Florida	Argonaut, LW Mod. Graphite Refl.	100.00	93	3.34	0.81	.17
Iowa State University	Argonaut, LW Mod.	100.00	93	3.02	0.00	0
Ohio State University	Pool, LW Moderated	10.00	93	3.18	3.95	.15
Purdue University	Pool, LW Mod. Plate fuel	1.00	93	2.05	0.00	0
Worcester Polytechnic Institute	Pool, LW Moderated	10.00	93	3.27	0.50	0
University of Kansas	Open pool, tank, LW Mod.	10.00	90	2.40	0.17	.24
University of Virginia	Pool, LW Cooled & Moderated	0.10	93	2.30	0.00	0
University of California, SB	L-77, LW Moderated	0.01	89	1.23	0.00	0
Rensselaer Polytechnic Institute	Critical Facility, LW Mod.	0.00	93	4.99	0.03	0
Manhattan College	ZPR, Pool, LW Moderated	0.00	92	3.02	0.08	0
Triga/Rod Type Fueled Reactors						
University of Illinois	Triga, Open tank, LW Moderated	1500.00	20	3.80	0.30	0
Pennsylvania State University	Triga, MK III Pool, LW Mod.	1000.00	20	4.37	0.00	0
Texas A&M University	Triga, LW Mod. FLIP fuel	1000.00	70	10.20	0.00	1.1
Washington State University	Triga, Pool, LW Moderated	1000.00	70	13.50	0.25	0
University of California	Triga, Pool, LW Moderated	1000.00	20	3.50	0.00	0
Oregon State University	Triga, LW Mod. FLIP fuel	1000.00	70	11.49	0.38	.82
University of Wisconsin	Triga, Pool, LW Mod. FLIP fuel	1000.00	70	11.10	2.02	.13
Kansas State University	Triga, Pool, LW Moderated	250.00	20	2.70	0.00	0
University of Maryland	Triga, Tank	250.00	20	3.40	0.00	0
Reed College	Triga, MK I, Pool LW Mod.	250.00	20	2.30	0.00	0
Columbia University	Triga, Pool, Not fueled	250.00	20	0.00	0.00	0
Michigan State University	Triga, MK I, Pool type	250.00	20	2.50	0.00	0
University of California, IR	Triga, MK-I, Pool, LW Moderated	250.00	20	2.29	0.00	0
University of Texas	Triga, MK-I Pool. LW Mod.	250.00	20	2.55	0.00	.71
University of Utah	Triga, Pool, LW Moderated	100.00	20	2.90	0.00	0
Cornell University	Triga, MK II, Pool type	100.00	19	3.00	0.00	0
University of Arizona	Triga, Pool LW Moderated	100.00	20	3.31	0.00	0
Brigham Young University	L-77, LW Mod. Liquid Fuel	0.01	20	1.38	0.00	0
Idaho State University	AGN-201	0.00	20	0.67	0.00	0
University of New Mexico	AGN-201	0.00	20	0.66	0.00	0
University of Oklahoma	AGN-211	0.01	20	0.81	0.00	0
Georgia Institute of Technology	AGN-201	0.00	20	0.66	0.00	0
Memphis State University	AGN-201	0.00	20	0.66	0.00	0
State University of New York	Pulstar, LW Mod. Open tank	2000.00	6	18.00	0.00	0
North Carolina State University	Pulstar, Pool type	1000.00	4	14.36	0.00	0

*KG Stored shown only for reactors with HEU Fuel.

1/ UCLA announced plans for closing the reactor in August.

Mr. Young. Thank you very much, Dr. Kane, for your testimony. Appreciate it.

Dr. Travelli, who is the manager of the Reduced Enrichment for Research and Test Reactor Program at Argonne National Laboratory. Dr. Travelli.

STATEMENT OF DR. ARMANDO TRAVELLI, MANAGER, REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTOR [RERTR] PROGRAM, ARGONNE NATIONAL LABORATORY

Dr. Travelli. Thank you, Mr. Chairman.

I appreciate this opportunity to address your subcommittees regarding the RERTR program goals, progress, and plans.,

The major thrust of my testimony is that the technical problems associated with HEU-to-LEU core conversions are well under control. It is virtually assured that given adequate funding the RERTR Program will develop fuels and fuel element designs allowing utilization of LEU in nearly all the research reactors which are now supplied by the United States. There is also a good probability that even the very few special reactors whose convertibility is not certain today will become convertible if the most advanced RERTR fuels are successful and/or if their element designs can be changed.

The RERTR Program was established by the Department of Energy in 1978. It is coordinated with the Department of State, with the Arms Control and Disarmament Agency and with the Nuclear Regulatory Commission. Its objective is to provide the technical means needed to utilize LEU instead of HEU fuels in research and test reactors without significant penalty in experiment capabilities, operation costs, component modifications, or safety characteristics.

Several LEU fuel types with high-uranium densities are being developed and tested for different reactor types. The goal of the new fuel types is to change reactor operation as little as possible. In particular, it is important: One, to ensure that both experimental capabilities and operating costs are not significantly affected; two, to facilitate licensing and minimize conversion costs by avoiding extensive component and fuel element modifications; three, to provide reprocessing services for LEU fuels that are comparable to those currently available for HEU fuels; four, to qualify fuel manufacturers as reliable suppliers of the new fuels as soon as possible; and five, to achieve safety characteristics which might facilitate generic licensing.

Development of these fuel types normally entails several phases. First, small plates, which we call miniplates, are fabricated, irradiated and examined. Second, the same operations are repeated for full-size elements, and third, full-core demonstrations are performed for a few reactor configurations of special interest.

In parallel with fuel development activities, the RERTR Program develops analytical methods and design options to evaluate and optimize the utilization of the new LEU fuels. Reactor performance is assessed with the new fuels for a variety of design configurations. Safety issues are addressed and the economics of the fuel cycle are studied. As part of its analytical activities, the RERTR Program also provides the executive branch with a technical and economic evaluation for each HEU export license application related to research reactors.

I will now summarize the major accomplishments of the RERTR Program during the past 6 years. The cooperation and the contributions of many domestic and foreign fuel fabricators and research reactors organizations have been essential to the progress which has been achieved. Current uranium densities used in HEU fuels range from .4 to 1.7 grams of uranium per cubic centimeter.

I would like to use the Vu-graph (fig. 1) because I have a table coming up which shows—otherwise, it would be difficult to follow.

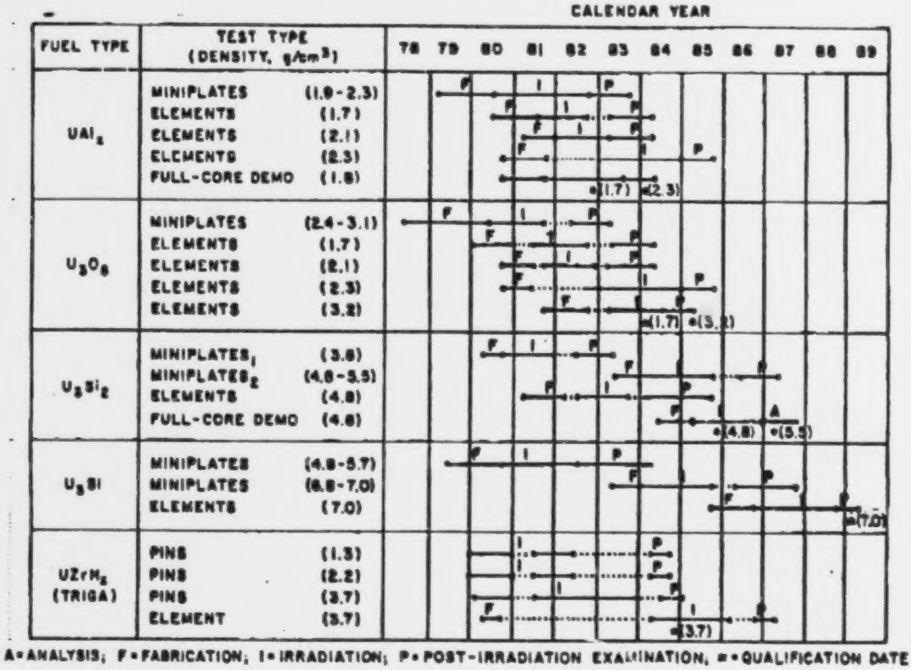

Fig. 1. Schematic Schedule for RERTR Fuel Development and Demonstration Activities.

Mr. YOUNG. Go ahead, Doctor.

Dr. TRAVELLI. The first achievement is that for miniplate and fuel element testing, the qualification dates achieved and projected for the various fuels are for plate-type reactors: UAl$_x$-Al, 1983, for 2.2 grams of uranium per cubic centimeter; U$_3$O$_8$-Al, 1985, with 3.2 grams of uranium per cubic centimeter; U$_3$Si$_2$-Al, 1985, for 4.8, and 1987 for 5.5 grams of uranium per cubic centimeter≧U$_3$Si-Al, 1989, for 7 grams of uranium per cubic centimeter.

And for rod-type reactors: UZ$_r$H$_x$, 1985, for 3.7 grams of uranium per cubic centimeter.

In going down the list, item 2 is the whole-core LEU fuel demonstrations. A: low-power. A whole-core—a whole core of LEU UAl$_x$-Al fuel with 1.7 grams per cubic centimeter was started in 1981 at the Ford Nuclear Reactor FNR at the University of Michigan. The results confirm the validity of RERTR calculations, methods and data related to safety and to performance. The operating characteristics of the FNR reactor are essentially unchanged with the LEU fuel and the reactor will continue to be fueled with LEU in the future.

And then B: high-power. A whole-core demonstration of U_3Si_2-Al fuel with LEU and 4.8 grams U per cc is planned to begin in the Oak Ridge research reactor beginning in mid-1985. The purpose of this demonstration is to validate the RERTR calculations, methods and data related to operational and fuel cycle characteristics.

Bids from three major fuel fabricators have been received and the—and negotiations are in progress for procuring fuel elements from all the three fuel fabricators.

Reprocessing. Savannah River Laboratory tests and studies have concluded that the RERTR fuels can be successfully reprocessed at the Savannah River plant.

Performance studies. Extensive studies have indicated a wide range of applicability of the new fuels to research reactors, both when they are moderated with light and when they are moderated with heavy water.

Safety studies. Extensive studies have indicated that the safety limits with LEU fuel do not differ considerably from the safety limits with HEU fuels.

Economic studies. Extensive studies have indicated that the new LEU fuels do not affect significantly the total fuel cycle and operating costs of most research reactors. This conclusion is conditioned to some extent by the ability of the commercial vendors to fabricate the new fuels effectively.

Joint conversion studies. Joint study programs are currently in progress with research organizations involving as many as 28 reactors in 17 countries.

Based on the RERTR program schedule, it will be technically feasible to convert a significant fraction of the foreign research reactors with 1 megawatt or more to LEU by 1986, but it is important to note that large quantities of HEU are required by the few reactors which need the most advanced fuels to convert. Corresponding projections about American research reactors would follow a similar pattern.

In conclusion, the RERTR program has made excellent progress in the development, demonstration and application of new LEU research reactor fuels with high uranium density. Two silicide fuels, U_3Si-Al and U_3Si_2-Al, are being vigorously pursued. U_3Si_2-Al is planned to be qualified with 4.8 grams per cubic centimeter at the end of 1985 and U_3Si-Al is planned to be qualified with 7 grams of uranium per cubic centimeter in 1989.

A whole-core demonstration with LEU U_3Si_2-Al fuel will begin in 1985, using fuel fabricated by commercial vendors.

International cooperation among fuel developers, commercial vendors and reactor operators has been essential to the progress which has been achieved. With continued international cooperation in the development and demonstration of the new technology, it will be feasible to significantly reduce HEU exports for research reactors in the next few years.

Mr. Chairman, attached to my statement is a report which describes the RERTR program in more detail. I submit it for the record and I will be available for any questions.

[The prepared statement of Dr. Travelli follows:]

Statement of

ARMANDO TRAVELLI
Manager, RERTR Program
Argonne National Laboratory

Before the

Subcommittees on
Energy Development and Applications
and
Energy Research and Production
Committee on Science and Technology
U. S. House of Representatives

September 25, 1984

Madam Chairman, Mister Chairman, and Members of the Subcommittees, I am Armando Travelli, Manager of the Reduced Enrichment Research and Test Reactor (RERTR) Program, centered at the Argonne National Laboratory. I appreciate this opportunity to address your Subcommittees regarding the RERTR Program goals, progress and plans.

The major thrust of my testimony is that the technical problems associated with HEU-to-LEU core conversions are well under control. It is virtually assured that, given adequate funding, the RERTR program will develop fuels and fuel element designs allowing use of LEU in nearly all the research reactors supplied by the U.S. There is also a good probability that even the very few special reactors whose convertibility is not certain today will become convertible if the most advanced RERTR fuels are successful and/or if their element designs can be changed.

The RERTR Program was established by the Department of Energy in 1978. The program is coordinated with the Department of State, the Arms Control and Disarmament Agency, and the Nuclear Regulatory Commission. Its objective is to provide the technical means needed to utilize LEU instead of HEU fuels in research and test reactors without significant penalty in experiment capabilities, operation costs, component modifications, or safety characteristics.

Several LEU fuel types with high uranium densities are being developed and tested for different reactor types. The goal of the new fuel types is to change reactor operation as little as possible. In particular, it is important (1) to ensure that both experimental capabilities and operating costs are not significantly affected; (2) to facilitate licensing and minimize conversion costs by avoiding extensive component and fuel element modifications; (3) to provide reprocessing services for LEU fuels that are comparable to those currently available for HEU fuels; (4) to qualify fuel manufacturers as reliable suppliers of the new fuels as soon as possible; and (5) to achieve safety characteristics which might facilitate generic licensing.

Development of these fuel types entails several phases. First, small plates (miniplates) or rods are fabricated, irradiated and examined. Second, the same operations are repeated for full-size elements. Third, full-core demonstrations are performed for some special reactor configurations.

In parallel with fuel development activities, the RERTR Program develops analytical methods and design options to evaluate and optimize the utilization of the new LEU fuels. Reactor performance is assessed with the new fuels for a variety of design configurations. Safety issues are addressed, and the economics of the fuel cycle are studied. As part of its analytical activities, the RERTR Program also provides the Executive Branch with a technical and economic evaluation for each HEU export license application related to research reactors.

The major accomplishments of the RERTR Program during the past six years are summarized below, combined with current schedules. The cooperation and contributions of many domestic and foreign fuel fabricators and research reactor organizations have been essential to the progress which has been achieved. Current uranium densities used in HEU fuels range from 0.4 to 1.7 g U/cm^3.

1. Miniplate and Fuel Element Testing

The qualification dates achieved and projected for the various fuels are:

Plate Type Reactors	
UAl_x-Al	1983 (2.2 g U/cm^3)
U_3O_8-Al	1985 (3.2 g U/cm^3)
U_3Si_2-Al	1985 (4.8 g U/cm^3), 1987 (5.5 g U/cm^3)
U_3Si-Al	1989 (7.0 g U/cm^3)
Rod Type Reactors	
$UZrH_x$	1985 (3.7 g U/cm^3)

2. Whole-Core LEU Fuel Demonstrations

(a) Low-Power

A whole-core demonstration with LEU UAl_x-Al fuel (1.7 g U/cm^3) began in 1981 in the Ford Nuclear Reactor at the University of Michigan. The results have confirmed the validity of RERTR calculations, methods and data related to performance and safety. The operating characteristics of the FNR are essentially unchanged with LEU fuel, and the reactor will continue to be operated with LEU fuel in the future.

(b) High-Power

A whole-core demonstration with LEU U_3Si_2-Al fuel (4.8 g U/cm^3) is planned in the ORR, beginning in mid-1985. The purpose of this demonstration is to validate RERTR calculations, methods and data related to operational and fuel cycle characteristics. Three major fuel fabricators have submitted bids and contract negotiations are in progress to procure elements from all three fabricators.

3. Reprocessing. Savannah River Laboratory tests and studies have concluded that RERTR fuels can be successfully reprocessed at the Savannah River Plant.

4. Performance Studies. Extensive studies indicate that the new LEU fuels have a wide range of applicability for conversion of both light- and heavy-water moderated research reactors.

5. Safety Studies. Extensive studies indicate that the safety limits with LEU fuel do not differ significantly from those with HEU fuel.

6. Economic Studies. Extensive studies indicate that the new LEU fuels will not significantly affect the total fuel cycle and operating costs of most reactors. This conclusion depends to some extent on the ability of the commercial vendors to manufacture the new LEU fuels efficiently.

7. Joint Conversion Studies. Joint study programs are in progress with research organizations involving as many as 28 reactors in 17 countries.

Based on the RERTR Program schedule, it will be technically feasible to convert a significant fraction of the foreign reactors with 1 MW or more by 1986, but it is important to note that large quantities of HEU are required by the few reactors which need the most advanced fuels to convert. Corresponding projections for U.S. research reactors would follow a similar pattern.

In conclusion, the RERTR Program has made excellent progress in the development, demonstration and application of new LEU research reactor fuels with high uranium density. Two silicide fuels (U_3Si_2-Al and U_3Si-Al) are being vigorously pursued: U_3Si_2-Al is planned to be qualified with 4.8 g U/cm^3 by the end of 1985, and U_3Si-Al is planned to be qualified with 7.0 g U/cm^3 in 1989. A whole-core demonstration with LEU U_3Si_2-Al fuel will begin in 1985 using fuel fabricated by commercial vendors.

International cooperation among fuel developers, commercial vendors, and reactor operators has been essential to the progress which has been achieved. With continued international cooperation in the development and demonstration of the new technology, it will be feasible to significantly reduce HEU exports for research reactors in the next few years.

Madam and Mister Chairman, attached to my statement is a report that describes the RERTR Program in more detail, and I submit it for the record. Thank you.

THE RERTR PROGRAM: GOALS, PROGRESS AND PLANS

ARMANDO TRAVELLI

Manager, RERTR Program
Argonne National Laboratory

A report supplementing testimony at a joint hearing of the
Subcommittee on Energy Development and Applications
and of the
Subcommittee on Energy Research and Production
Committee of Science and Technology
U. S. House of Representatives

September 25, 1984

THE RERTR PROGRAM: GOALS, PROGRESS AND PLANS

ABSTRACT

The status of the U.S. Reduced Enrichment Research and Test Reactor (RERTR) Program is reviewed. After a brief outline of RERTR Program objectives and goals, program accomplishments are discussed with emphasis on the development, demonstration and application of new LEU fuels. Most program activities have proceeded as planned, and a combination of two silicide fuels (U_3Si_2-Al and U_3Si-Al) holds excellent promise for achieving the long-term program goals. Current plans and schedules project the uranium density of qualified RERTR fuels for plate-type reactors to grow by approximately 1 g U/cm^3 each year, from the nearly null value of 1982 to the 7.0 g U/cm^3 which will be reached in early 1989. The technical needs of research reactors for HEU exports are also estimated to undergo a gradual but dramatic decline in the coming years.

HISTORICAL BACKGROUND

One hundred thirty-seven research and test reactors (92 foreign, 45 U.S.) using High-Enrichment-Uranium (HEU, ≥20% enrichment) of U.S. or other Western origin are currently in operation in thirty-four countries. The cumulative power of these reactors is 1370 MW, and their annual ^{235}U requirement is about 1025 kg. The average cycle time of a fuel element lasts approximately 4 years, so that about 4100 kg of HEU are in continuous circulation to fuel these reactors. There is concern that some of this material may be diverted to make nuclear weapons, especially when it is in the unirradiated state.

Originally, and as recently as the early 1960's, only Low-Enrichment-Uranium (LEU, <20% enrichment) was meant to be exported by the U.S. for use in research reactors. The research reactors considered in the "Atoms for Peace" program were LEU-fueled, and so was the "Geneva Reactor" (1955). As power and neutron flux were revised in research reactors to satisfy more demanding experimental requirements, greater ^{235}U loadings of the fuel elements began to be needed to avoid the financial penalty of a reduced fuel lifetime. The increased loadings could have been achieved either by continuing the development of fuels with higher uranium density or by increasing the uranium enrichment. Of the two choices, the latter prevailed in the 1960's. HEU became freely available and research reactor fuel development was terminated. HEU became of common use in research reactors and was applied even in those reactors where LEU would have been adequate.

Against this background, renewed concerns about nuclear proliferation emerged in the late 1970's. Both the International Nuclear Fuel Cycle Evaluation (INFCE) Program and the Nuclear Alternative Systems Assessment Program (NASAP) concluded that the risk of international nuclear proliferation depends strongly on the magnitude and accessibility of inventories of weapons-usable fissile materials. Several countries expressed deep concern about this problem. In particular, the U.S. announced a Nuclear Non-Proliferation Act Initiative to significantly reduce U.S.-supplied HEU inventories for fueling research and test reactors, and plans for the RERTR Program to develop safe and viable alternative uranium-based fuels of significantly reduced enrichment. One of the major goals of the RERTR Program is to reverse the trend that prevailed in the 1960's, and to concentrate on renewed fuel development, demonstration and design activities to provide the technical foundation which will allow research and test reactors to achieve their performance/safety/economics goals without reliance on HEU materials.

THE RERTR PROGRAM, ITS OBJECTIVES AND GOALS

The Reduced Enrichment Research and Test Reactor (RERTR) Program was established by the U.S. Department of Energy in 1978 (and is coordinated with the U.S. Department of State, the U.S. Arms Control and Disarmament Agency, and the U.S. Nuclear Regulatory Commission) to provide the technical means needed to utilize LEU instead of HEU fuels in research and test reactors, and to do so without significant penalty in experiment capabilities, operation costs, component modifications, or safety characteristics.

Four main LEU fuel types are being developed with high uranium densities for different reactor types:

Aluminide Fuels (UAl_x-Al). Used in plate-type reactors. Current normal uranium density range with HEU is 0.4-0.8 g U/cm^3, with peak density of 1.7 g U/cm^3. Estimated highest practical density is 2.3 g U/cm^3.

Oxide Fuels (U_3O_8-Al). Used in plate-type reactors. Current normal uranium density with HEU is ~0.8 g U/cm^3, with peak density of 1.3 g U/cm^3. Estimated highest practical density is 3.2 g U/cm^3.

Silicide Fuels (U_3Si_2-Al, U_3Si-Al). Being developed and demonstrated by the RERTR Program for application in plate-type reactors. Estimated highest practical density is 5.5 g U/cm^3 with U_3Si_2-Al, 7.0 g U/cm^3 with U_3Si-Al. A variation of this fuel (U_3SiAl-Al) is under development by the Canadian AECL for application in rod-type reactors.

TRIGA fuels ($UZrH_x$). Used in rod-type reactors. Current uranium density with HEU is 0.5 g U/cm^3. Developed by GA Technologies and being tested in cooperation with the RERTR Program for densities up to 3.7 g U/cm^3.

Development of each fuel type normally entails several consecutive phases. First, small plates (miniplates) for plate-type fuel or rods for rod-type fuel are fabricated, irradiated and subjected to Post-Irradiation-Examinations (PIEs) to screen the most promising candidates. Second, full-size elements of the types identified by the miniplate tests are fabricated, irradiated, and examined to test their behavior under irradiation. Third, full-core demonstrations are performed for some reactor configurations of general interest, but not for each fuel type, to demonstrate that the new fuels provide the desired experimental capabilities, economics, and safety characteristics when used to fuel an entire reactor core.

The new fuel types are meant to be simple to fabricate, and to require equipment and procedures very similar to those of current fuels. The goal is to have the enrichment change perturb as little as possible every aspect of reactor operation, and to minimize potential economic penalties or conflicts. In particular, it is desirable (1) for all current fuel manufacturers to become as soon as possible qualified and active producers of the new fuels, without the enrichment change affecting their competitive position; (2) to avoid extensive modifications of safety analysis reports, by using geometric configurations close to those previously used; (3) to have fuel cycle services for spent LEU fuels available under conditions comparable to those proffered for the spent HEU fuels to be displaced, and (4) to insure that both experimental capabilities and fuel cycle costs are not significantly penalized by the conversion to LEU fuel.

In parallel with the fuel development activities, the RERTR Program develops analytical methods and design options to evaluate and optimize the utilization of the new LEU fuels as they are developed. The performance of reactors of special interest is assessed with the new fuels in a variety of design configurations; safety issues are addressed; and the economics of the fuel cycle are studied to determine the combination of fuel material/design/operation which will optimize the overall reactor performance with LEU fuel. An important vehicle for the validation of the results of these studies, and for their international acceptance, is their inclusion in International Atomic Energy Agency (IAEA) guidebooks which are developed by a large group of international consultants coordinated by the IAEA and then published and distributed by the IAEA.[1,2] As part of its analytical activities, the RERTR Program also provides the U.S. Executive Branch with technical and economic evaluations of each HEU Export License Application related to HEU use in research reactors.

ACCOMPLISHMENTS

The goals of the RERTR Program have been aggressively pursued during the past six years, in cooperation with many research reactor organizations and with domestic and foreign fuel fabricators. The main achievements are summarized below. More detailed information about RERTR fuel development and demonstration activities is provided in Ref. 3.

1. UAl_x-Al Fuels. Miniplates with up to 2.5 g U/cm^3 have been fabricated with LEU by EG&G, NUKEM and the Argentinian Comision Nacional de Energia Atomica (CNEA), and irradiated to 89-96% burnup in the Oak Ridge Research Reactor (ORR). PIE results are excellent. Full-size elements with 1.7, 2.1, and 2.3 g U/cm^3 have been fabricated through the combined efforts of CERCA and NUKEM. ORR irradiation of the less dense elements is complete with good PIE results, while irradiation of the denser elements continues.

2. U_3O_8-Al Fuels. Miniplates with LEU and up to 3.6 g U/cm^3 have been fabricated by ORNL, NUKEM and the CNEA, irradiated to 80-98% burnup in the ORR, and examinded. PIE results are good. Full-size elements with 1.7, 2.1, 2.3, and 3.2 g U/cm^3 have been fabricated through the combined efforts of NUKEM, CERCA and TI. ORR irradiation of the less dense elements is complete with good PIE results, while irradiation of the denser elements continues.

3. U_3Si_2-Al Fuels. Miniplates with up to 3.8 g U/cm^3 have been fabricated by ANL and irradiated to 90-96% burnup in the ORR. PIE results are excellent.[4] Miniplates with up to 5.7 g U/cm^3 have been fabricated by ANL and are being irradiated in the ORR. Six full-size elements with 4.8 g U/cm3, fabricated by NUKEM, CERCA and Babcock & Wilcox (B&W), have been irradiated in the ORR. PIEs of the first element to reach ~50% burnup have given excellent results. Visual examination of the elements with ~75% burnup has also given good results.

4. U_3Si-Al Fuels. Miniplates with up to 6.1 g U/cm^3 have been fabricated by ANL and the CNEA, and irradiated to 84-96% burnup in the ORR. The PIE results have been good, but show that some burnup limits may need to be imposed for the higher densities. Miniplates with up to 7.2 g U/cm^3, fabricated by ANL and NUKEM, are currently being irradiated in the ORR. Four full-size fuel plates, two at 5.5 g U/cm^3 and two at 6.0 g U/cm^3, were fabricated by CERCA and irradiated in SILOE under a cooperative agreement with the RERTR Program. The plate with the highest burnup is estimated to have reached over 55% average burnup without excessive thickness increase. A full-size SILOE test element with 6.0 g U/cm^3 has been fabricated by CERCA and is now being irradiated.

5. $UZrH_x$ Fuels. Full-size pins, with densities of 1.3, 2.2, and 3.7 g U/cm^3, were fabricated by GA Technologies and irradiated in the ORR beginning in 1980. Two of these pins failed during FY 1984 after reaching burnups of 54% and 66%, respectively, both in excess of the original goal (50%). The failures, still under investigation, appear to be related to the behavior of the clad and not to that of the fuel itself.

6. Low-Power, Whole-Core LEU Fuel Demonstration. A whole-core LEU demonstration with UAl_x-Al fuel (1.7 g U/cm^3) began in 1981 in the Ford Nuclear Reactor (FNR) at the University of Michigan. The results have confirmed the validity of the calculations, methods and data used to predict performance and safety characteristics of research reactors undergoing conversion.[5] The operating characteristics of the FNR are essentially unchanged with the LEU fuel, and the reactor will continue to be operated with LEU fuel in the future.

7. High-Power, Whole-Core LEU Fuel Demonstration. A whole-core LEU demonstration with U_3Si_2-Al fuel (4.8 g U/cm^3) is planned in the ORR, beginning in mid-1985. This demonstration is to verify the validity of calculations, methods and data used to predict operational and fuel cycle characteristics of research reactors undergoing conversion. The demonstration is also to develop the commercial production capability of several vendors for U_3Si_2-Al fuels. Three major fuel fabricators have submitted bids for fabricating elements for the demonstration core. The bids are technically sound and contract negotiations are under way for procuring elements from all three fabricators.

8. Reprocessing. Savannah River Laboratory tests and studies have concluded that RERTR silicide, oxide and aluminide fuels can be successfully reprocessed at the Savannah River Plant.[6]

9. Generic Conversion Studies. Extensive generic studies have indicated a wide range of applicability of the new fuels to the conversion of both light- and heavy-water moderated research reactors. Much of these studies were included in IAEA guidebooks.[1]

10. Generic Safety Studies. Extensive generic studies have addressed the safety and licensing aspects of research reactor conversions, with favorable results. Much of these studies are being included in an IAEA guidebook.[2]

11. Economic Studies. The new fuels have been shown to offer considerable potential for economic advantages in many research reactors undergoing conversion.[7]

12. Joint Conversion Studies. Joint study programs for the conversion of specific reactors have been in progress with research organizations involving as many as 28 reactors in 17 countries.

PLANS, SCHEDULES, AND IMPLICATIONS FOR FUTURE AVAILABILITY OF LEU FUELS

The fuel development and demonstration activities which normally define the program's critical path fit into the schedule illustrated in Fig. 1. Asterisks mark the dates when all information needed to make some particular fuels qualified and licensable for use in research reactors is expected to have been compiled. The corresponding uranium densities are indicated in parenthesis.

For each fuel the following qualification dates emerge for intermediate and final uranium densities (g U/cm^3):

UAl_x-Al	1982 (1.7)	1984 (2.3)
U_3O_8-Al	1984 (1.7)	1985 (3.2)
U_3Si_2-Al	1985 (4.8)	1987 (5.5)
U_3Si-Al		1989 (7.0)
$UZrH_x$		1984 (3.7)

The cumulative uranium density expected to become qualified for application in plate-type LEU research and test reactor fuels is plotted as a function of time in Fig. 2. The density increases in several discontinuous steps from the nearly null value of 1982 to the 7.0 g U/cm^3 which will become qualified in 1989. The progress in qualified density can be also approximated as a straight line, with a rate of increase close to 1 g U/cm^3 per year.

The gradual increase of the qualified uranium density leads to a correspondingly gradual increase in the amount of HEU which will no longer need to be exported for the operation of research reactors.[1] The histogram which provides current estimates for this value as a function of time is shown in Fig. 3.

The near-term fuels (UAl_x-Al, U_3O_8-Al, and $UZrH_x$), U_3Si_2-Al and U_3Si-Al are responsible for nearly equal percentages (~28% each), of the total anticipated HEU export decrease, and are supplemented by the contribution of U_3SiAl-Al fuel rods developed in Canada. The largest numbers of potential reactor conversions are represented by the steps occurring in 1985 and 1986 (24 and 14 reactors with powers no less than 1 MW, respectively) but the few reactors for which the high densities provided by the U_3Si-Al fuel are needed correspond to a large fraction of the HEU exports.

The data shown in Fig. 3 apply to research reactors with power in excess of 1 MW and located in countries other than the U.S. A plot of the corresponding anticipated potential decrease of HEU usage in U.S. research reactors would show a similar pattern.

SUMMARY AND CONCLUSION

The RERTR Program has made significant progress in the development, demonstration and application of new LEU research reactor fuels with high uranium density. Two different forms of silicide fuels (U_3Si_2-Al and U_3Si-Al) are vigorously pursued: the former will be qualified with 4.8 g U/cm^3 at the end of 1985, and the latter will be qualified with 7.0 g U/cm^3 in early 1989. A whole-core demonstration utilizing U_3Si_2-Al fuel is planned for 1985.

The fuel fabrication technology developed by the RERTR has been transferred to commercial fuel fabricators through an extensive and continuous exchange of information. All major research reactor fuel fabricators have been actively cooperating with the program, and have on several occasions made significant contributions to its progress.

According to the program schedule, the qualified uranium density in the fuel meat of RERTR plate-type fuels will increase at an almost uniform rate from the nearly null value of 1982 to the 7.0 g U/cm^3 scheduled for 1989. The percentage of 1982 HEU average annual exports which will be technically replaceable with LEU fuels will also grow at an almost uniform rate and will tend to reach the 100% mark in early 1989.

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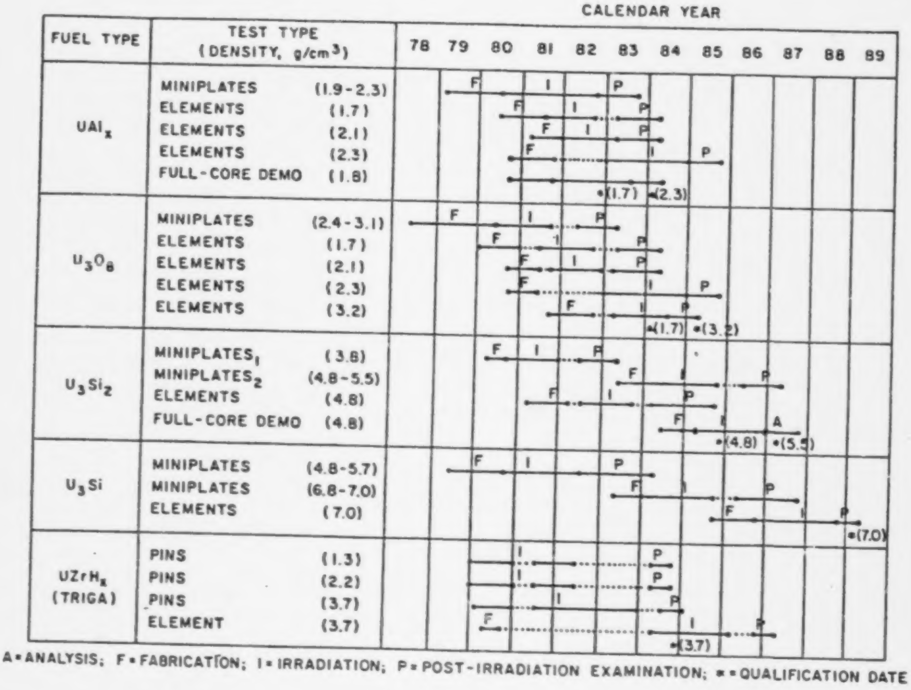

Fig. 1. Schematic Schedule for RERTR Fuel Development and Demonstration Activities.

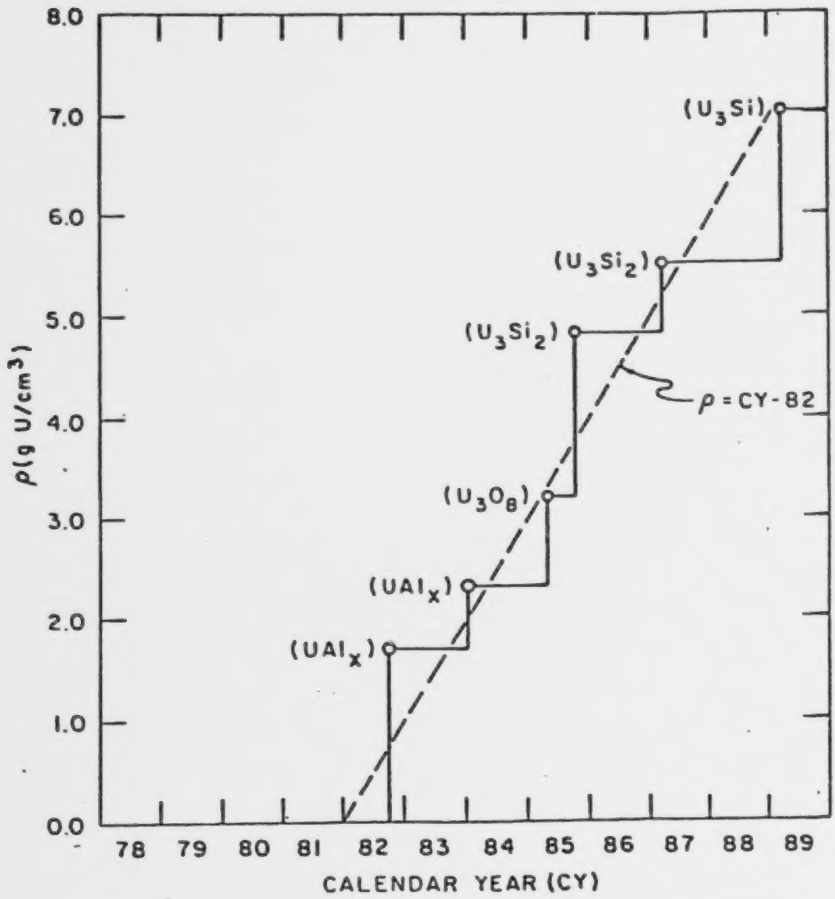

Fig. 2. Projected Uranium-density Progress for Plate-Type Fuel Qualification

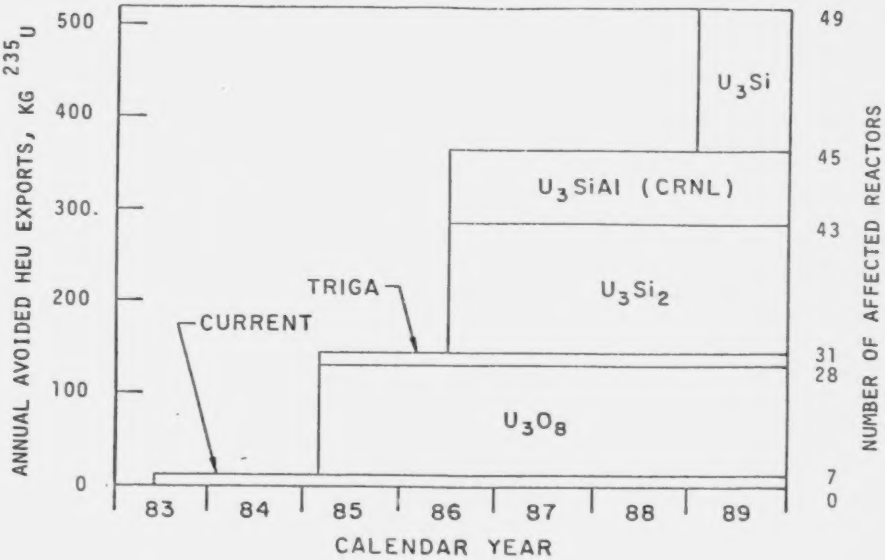

Fig. 3. Potential Avoided U.S. HEU Exports for Research and Test Reactor Fuels.

Biography

DR. ARMANDO TRAVELLI
Manager, RERTR Program
Argonne National Laboratory

Dr. Travelli has been responsible for management and direction of the Reduced Enrichment Research and Test Reactor (RERTR) Program since its inception. The program includes activities in many areas related to the utilization of reduced enrichment fuels in research reactors and, in particular, fuel development and demonstration, neutronics, thermalhydraulics, reprocessing, safety, and economics.

Dr. Travelli holds a Ph.D. in Nuclear Engineering and Science from the Rensselaer Polytechnic Institute and a Doctorate in Chemical Engineering from the University of Rome, Italy. After teaching Nuclear Nuclear Reactor Physics for two years at the Massachusetts Institute of Technology, he joined Argonne in 1965. He has been involved in nuclear reactor physics, safety, and test facilities design. He has authored approximately seventy publications in these fields.

Mr. **Young**. Without objection, Doctor, your full statement will be made a part of the record and I'd like to apologize to this panel. There's another rollcall on this very important resolution; it's the continuing resolution. I guess we're going to spend about $800 billion of the taxpayers' money in the next year or so.

I'll be back just as soon as I possibly can and maybe we could ask you a few questions or for the committee, if we submitted some of the questions to you in writing, that you would be kind enough to respond so they could be left—the record would be left open so your response could be made a part of the record.

Is that—I believe we have one more panel that would follow—would follow this panel here.

If this panel would not mind waiting, I'll be back as soon as I can, maybe to ask each one of you at least one question on the subject matter that you covered. I would appreciate it very much.

The committee will stand in recess for about 10 minutes.

[Recess.]

Mr. **Young**. Mr. Stoiber, does the Department of State support the NRC's proposed rule?

Mr. **Stoiber**. I would say that we—we take a somewhat nuanced position in regarding it. We see the desirability of moving toward conversions when it is economically technically feasible for domestic research reactors, however, we share the view of the Department of Energy on the problems that would be associated, particularly with converting lifetime-fueled reactors and we don't see that this makes much sense at the present time.

I think the important part of our testimony is that foreign reactor operators and governments will be looking at the U.S. program to see what we do, but that that will only be one factor in the many factors that they will be considering in determining what steps they take to convert.

So we think—although it is a fact—it is going to be a factor, it is not the overriding factor and should not be overemphasized.

Mr. **Young**. Thank you very much.

Dr. Kane, I think we have two questions for you, sir. You note in your testimony that DOE has volunteered to store unirradiated HEU fuel at secure DOE sites. How much HEU is involved and what are the estimated incremental transportation costs and who would pay these costs?

Dr. **Kane**. All right, let me take those in order. I probably almost have to guess about how much we can reduce the inventory by storage at DOE sites, and I think that if we could—the current total inventory of unirradiated fuels stored at all these reactors, from large to small, is about 28 kilograms, and I think it's reasonable by good housekeeping and encouraging universities to let us store their fuel and by us making it convenient for them, that we could cut that in half, perhaps.

Don't make that too accurate, but let's say 12 to 15 kilograms could be the inventory of unirradiated HEU fuel that we could arrive at.

Normally, we do not pay the transportation costs. That was kind of the second part of your question, so that would have to be universities, as far as I know.

Mr. Young. In the universities, and the third part would be, they would be paying the costs?

Dr. Kane. Yes. We would pay for the space to store it and all that, but the transportation itself would be the universities responsibility.

Mr. Young. Is DOE considering converting any of its research reactors to the LEU fuel?

Dr. Kane. You saved the hard one for last, didn't you? [Laughter.]

This one'll take maybe a minute or two to answer that one reasonably. The DOE has, to my knowledge, about four high-power research reactors and let me just name them: The ATR out in Idaho; the HFBR at Brookhaven National Lab; the HFIR at Oak Ridge National Lab; and the ORR at Oak Ridge National Lab. Now, the ORR is going to be, as Dr. Trevelli said, a demonstration for the low-enriched uranium. It's the easiest to convert, by the way, too.

I'd say on the question—let me—I think dismiss the test reactor in Idaho. That would be very difficult technically to convert, and also, it is in a very high-security area. It's on the Idaho site. Reprocessing facilities aren't far away. This is a high-security area and I think that the inclination would be we would not convert that one.

Now, this is just my personal opinion based on what I see at the present time.

Now you've gotten me down to the really tough question, what will we do about the HFBR and the HFIR? I think what we will do is wait until the technical—both of those are kind of on the edge of difficulty. They will be hard to convert with the low-enriched fuel. I think we'll have to see what the progress of that demonstration is and at that time, make a decision and it'll be based on a number of things.

What will we sacrifice by converting and you do sacrifice probably—a study will show—we'll do a study on those reactors and try to get the pros and cons and our other alternatives—again, I think the security at the sites of those two reactors at Oak Ridge and at Brookhaven are far beyond what any university could afford. We may choose not to convert and to upgrade our security rather than convert, but I think that's a decision we probably won't make for several years yet.

Sorry for the long answer.

Mr. Young. No, that's fine. It makes sense. Thank you very much.

Dr. Travelli, could you please clarify the fiscal year 1985 budget situation with regard to the RERTR program. We understand that there was a $700,000 shortfall. Does this shortfall still exist, and if so, what would be the impact on the schedule?

Dr. Travelli. I would like to ask the question, if I may——

Mr. Young. Happy to.

Dr. Travelli [continuing]. Of Dave Bailey.

Mr. Young. Yes, sir.

Mr. Bailey. I'm Dave Bailey, Office of Spent Fuel Management and Reprocessing——

Mr. YOUNG. Would you mind coming up next to Dr.—next to Dr. Travelli and I think if you'd give your name, it would be maybe helpful to the committee and your title.

Mr. BAILEY. My name is David Bailey. I'm in the Office of Spent Fuel Management and Reprocessing Systems within the Office of Nuclear Energy, responsible for management of the RERTR Program within NE.

The fiscal year 1985 funding is less than we originally planned. In the shortfall figures, the numbers have varied during the course of looking at the fiscal year 1985 scope. We think that we have gone into the program's scope, made adaptations to it and have priortized the fiscal year 1985 program so that we can meet the major program milestones without significant delay.

We would hope that the fiscal year 1986 funding that's provided—that is, as I understand it, in the active budget would provide sufficient funding to allow us to resume some of those lower-priority activities that were deferred.

Mr. YOUNG. Well, thank you very much, Mr. Bailey.

Gentlemen, thank you very much. We will, as I mentioned earlier, we will submit the balance of the questions and if you would send your answers back to the committee, the committee would appreciate it.

Thank you all very much for your appearance here today.

The next panel, research and test reactor operators and users. Gentlemen, thank you very much. The first witness on our left, and this is not alphabetically done so I just follow the line that says Dr. Robert S. Carter, Chief of Reactor Radiation, National Bureau of Standards, U.S. Department of Commerce. Dr. Carter, without objection, your full statement will be made a part of the record and you might summarize, sir, in the manner that you'd like.

STATEMENT OF DR. ROBERT S. CARTER, CHIEF, REACTOR RADIATION DIVISION, NATIONAL BUREAU OF STANDARDS, U.S. DEPARTMENT OF COMMERCE

Dr. CARTER. Thank you, Mr. Chairman.

My name is Robert S. Carter and I am Chief of the Reactor Radiation Division of the National Bureau of Standards, which is an agency of the Department of Commerce.

I am pleased to have this opportunity to present testimony on the proposal to convert domestic research and test reactors to low-enriched uranium fuel. The National Bureau of Standards operates a high-performance research reactor. High-performance reactors are designed to provide advanced research capabilities.

I will address my comments primarily to the effect which the proposed conversion to low-enriched uranium would have on such reactors. I will use the NBS reactor as an example, but my remarks are generally applicable to all high-performance research reactors.

The NBS reactor is licensed by the Nuclear Regulatory Commission to operate at 20 megawatts and designed to provide the maximum research capability for the power that it operates at. This is achieved by using highly enriched uranium fuel, heavy water as a moderator instead of the more conventional regular water and a unique core configuration to improve the quality of the neutron beams used in research.

Thus, as is the case with all high-performance reactors, a great deal of effort and expense has gone into optimizing reactor performance.

Safety is, of course, of major importance. The highly enriched fuel used at present in all high-performance research reactors in the United States has been in use for more than 30 years with an outstanding safety record.

Research reactors provide many important services. They are used to train nuclear engineers and are a major source of medical isotopes. They are used extensively to measure trace elements in many materials and for nondestructive testing of materials and components. High-performance research reactors are used more and more by industrial research scientists to develop new materials and processes.

They are becoming increasingly important to the whole field of material science, the science that underlies much of our technological future and international competitiveness. Recently, a committee of the National Academy of Sciences was set up to recommend national priorities for the development of major facilities for material science research. Its highest priority recommendation was the development of the Center for Cold Neutron Research at a high-performance reactor. This is an area where the United States is far behind western Europe, making it more difficult for the United States to compete in the field of high-technology materials.

The NBS reactor, which is licensed, is one of only two reactors in the United States where such a center could be set up. Thus, licensed research reactors, as well as the Department of Energy reactors, make major contributions to areas of national concern.

There is no technological need for the mandatory conversion of licensed research and test reactors from high-enriched to low-enriched fuel. The high-enriched fuel is more versatile and has an outstanding safety record of many years in a large variety of reactors. It provides the longest fuel element lifetime and minimizes the cost of reactor operation.

Low-enriched fuel does not have an established safety record and would not benefit the cost or efficiency of reactor operation. The possibility of theft of highly enriched fuel to make an explosive nuclear device must be considered. However, no licensed research reactor has enough unirradiated fuel on site to make a nuclear device, so the simultaneous theft from more than one facility would be required.

All research reactors have procedures to safeguard the fuel which have been reviewed by the Nuclear Regulatory Commission and found to provide adequate protection. Therefore, present safeguards appear adequate and conversion to low-energy fuel in order to further decrease the domestic risk of diversion of high-enriched fuel does not appear necessary.

In order to reduce the international traffic in highly enriched uranium, overseas reactors are being encouraged to convert to low-enriched fuel. However, they would not be required to return their high-enriched fuel but only to use low-enriched uranium in their replacement fuel.

On the other hand, the Nuclear Regulatory Commission's proposed rule would require domestic licensed reactors to return unused high-enriched fuel and replace it with low-enriched fuel. This would require even those very low-power reactors with so-called lifetime cores to replace their present fuel with low-enriched fuel.

Although the proposed rule goes far beyond the requirements under consideration for overseas reactors, it would not directly affect international traffic in high-enriched fuel because it applies only to domestic licensed reactors. Furthermore, licensed reactors use only 10 percent of the high-enriched fuel used in U.S. research reactors, the other being used in DOE reactors.

Thus, any indirect effect, such as setting an example for overseas reactors to follow, would also appear to be quite limited.

The impact of converting high-performance research reactors to low-enriched fuel would be to decrease their productivity, lower their efficiency of operation and possibly lower their margin of safety. Conversion to low-enriched fuel would decrease the quality of the research beams by up to 25 percent. This would include 10- to 12 percent reduction in the beam intensity and corresponding increase in background, giving an overall reduction of—in some cases, as much as 25 percent. This is a severe penalty to pay when the United States is already far behind our overseas competitors in this area of research which is so important to the development of advanced technologies.

The conversion to low-enriched fuel would also adversely impact the efficiency of reactor operation. High-performance reactors use higher concentrations of Uranium 235 in their fuel than is available in the recently low-enriched fuels. The so-called high loading extends the life of the fuel elements and significantly reduces the cost of fueling the reactor.

Even if the DOE efforts to develop advanced fuels are successful, the fuel lifetime would be decreased resulting in increased operating—resulting in increases in operating expenses.

The fuels under development by DOE to meet the higher loading required for high-performance reactors use different materials than those that have been used previously. A few prototype elements may be tested extensively, but that testing is very limited compared to the thousands of high-enriched elements that have a demonstrated safety record over many years.

High-performance reactors normally push their fuel to the safe limit as established by years of experience in the use of high-enriched fuel and it would be unwise to mandate the conversion of high-performance reactors to new fuels with the limited testing experience.

The estimates by DOE and NRC of the total cost of conversion of all university reactors varys from $8 to $15 million—I believe the DOE has been saying $12 million in these hearings—if the proposed rule is followed. These cost estimates do not include the cost for reactors in the private sector, nor for the NBS reactor. The cost of replacing the existing inventory of unused fuel, including the cost of fabrication, shipping and reprocessing, would be about $2 million for the NBS reactor alone, and the increase in annual operating cost is estimated to be about $600,000.

This, of course, does not include the loss of reactor productivity and the resulting negative impact on U.S. scientific and technological capability.

In summary, the NBS sees no technological need to convert to low-enriched fuels. Conversion would adversely affect the productivity of high-performance reactors. There appears to be little need to further reduce the risk of a domestic diversion of high-enriched uranium and the proposed domestic action will have little affect on international traffic in high-enriched uranium.

In order to regain a position of leadership in research reactor capability and improve U.S. competitiveness in many areas of advanced technology, it will be necessary to do everything possible to upgrade existing reactors and provide full flexibility for the design of new advanced reactors. NBS believes the mandatory conversion to low-enriched fuels would severely limit the Nation's option in achieving these objectives.

Thank you. I'll be pleased to answer any questions.

[The prepared statement of Dr. Carter follows:]

U.S. DEPARTMENT OF COMMERCE

STATEMENT BY ROBERT S. CARTER
CHIEF, REACTOR RADIATION DIVISION
NATIONAL BUREAU OF STANDARDS
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
AND THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SEPTEMBER 25, 1984
ON THE CONVERSION OF DOMESTIC RESEARCH AND TEST REACTORS
TO LOW-ENRICHED URANIUM FUEL

Mr. Chairman, Madam Chairwoman and Members of the Subcommittees:

My name is Robert S. Carter, and I am chief of the Reactor Radiation Division of the National Bureau of Standards, an agency of the Department of Commerce. I am pleased to have this opportunity to present testimony on the proposal to convert domestic research and test reactors to low-enriched uranium (LEU) fuel.

The National Bureau of Standards operates a high-performance research reactor. There are many types of research reactors, ranging from those operating at such low power that they never need to refuel to high-power reactors designed to provide advanced research capabilities. I will address my comments primarily to the effect which the proposed conversion from high-enriched uranium (HEU) fuel to low-enriched uranium fuel would have on high-performance reactors. I will use the NBS reactor (NBSR) as an example, but my remarks are generally applicable to all high-performance reactors including the Department of Energy reactors for which no conversion is proposed as well as to those licensed by the Nuclear Regulatory Commission. Before addressing the need for conversion and potential impacts, I will describe some of the steps taken to optimize high-performance reactors using the NBS reactor as an example, and demonstrate the valuable contributions research reactors make to areas of national concern.

THE NBS REACTOR

The NBS reactor is licensed by the Nuclear Regulatory Commission (NRC) to operate at 20 MW and designed to provide the maximum research capability for its power. This is achieved by using highly enriched uranium fuel, heavy water (D_2O) as a moderator instead of the more conventional regular water, and a unique core configuration to improve the quality of the neutron beams used in the research. Great care has been taken in the design of the instruments that are used with the reactor to take full advantage of the capabilities of the reactor itself. Thus, a great deal of effort and expense has gone into optimizing its performance. All high-performance reactors include similar special features to maximize their performance.

Safety is, of course, of major importance. The highly enriched fuel used at present in all high-performance research reactors in the U.S. has been in use for more than thirty years, with an outstanding safety record. The use of highly enriched uranium also makes it possible to put more fuel in each element which prolongs the useful life of the element and reduces operating expenses significantly.

CONTRIBUTIONS OF RESEARCH REACTORS TO AREAS OF NATIONAL CONCERN

Research reactors provide many important services. They are an important educational facility in many nuclear engineering departments. They are a major source of medical isotopes and are used extensively to determine trace elements in foods and drugs and measure the level of pollutants in the environment. They are used extensively for the nondestructive testing of materials and components. The high-performance reactors make major contributions to the development of new materials and technologies. More and more industrial research scientists are using the measurement methods available only at high-performance reactors to develop new materials and processes. For example, scientists from industry are using the NBS reactor to study the properties and behavior of new types of chemical catalysts. The properties of entirely new types of metal alloys and ceramics are being determined, and the detailed mechanisms that lead to the embrittlement of welds by small amounts of hydrogen impurities are being studied.

The facilities at research reactors are becoming increasingly important to the whole field of material science--the science that underlies much of our technological future and international competitiveness. In fact, a committee of the National Academy of Sciences, set up to recommend national priorities for the development of major facilities for materials science research, recommended as the top short-term priority the development of a Center for Cold Neutron Research at a high-performance reactor. This is an area where the U.S. is far behind Western Europe making it more difficult for the U.S. to compete in the field of high-technology materials. The NBS reactor, which is licensed, is one of only two reactors in the U.S. where such a center could be set up.

These examples illustrate the value of high-performance reactors and demonstrate that licensed research reactors as well as the Department of Energy (DOE) reactors make major contributions to areas of national concern.

NEED FOR CONVERSION

There is no technological need for the mandatory conversion of licensed research and test reactors from HEU fuel to LEU fuel. The HEU fuel is more versatile and has an outstanding safety record of many years in a large variety of reactors. It provides the longest fuel element lifetime and minimizes the cost of reactor operation. LEU fuel does not have an established safety record and would not benefit the cost or efficiency of reactor operation.

The protection of highly enriched fuel from theft cannot be taken lightly since the uranium enrichment is adequate for the construction of an explosive nuclear device if enough material could be assembled. However, extensive and complex chemical purification would be required to separate the uranium from the metal matrix in which it is dispersed in research reactor fuel. The minimum amount of highly enriched uranium required to make a nuclear device is classified, but, as used in licensing regulations, the amount required is understood to be less than the so called formula quantity. No licensed research reactor has more than a formula quantity of unirradiated fuel, so theft from a single facility would not provide enough material for a nuclear device. All research reactors have procedures to safeguard their fuel. Each plan has been reviewed by the NRC and found to provide adequate protection. The NRC's Division of Safeguards has stated that there has never been an attempted theft of fuel from a research reactor and that no known domestic threat exists. Therefore, present safeguards appear adequate and conversion to low-enriched fuel in order to further decrease the domestic risk of diversion of HEU fuel does not appear necessary. Some operators of small reactors in which the conversion to low-enriched uranium would have little technical impact might wish to convert voluntarily to reduce their existing safeguards requirement.

The goal stated by the NRC for encouraging overseas reactors to convert to LEU fuel is to reduce the international traffic in highly enriched uranium to decrease the risk of diversion. Overseas reactors would not be required to return their HEU fuel but only to use low-enriched uranium in their replacement fuel. The Nuclear Regulatory Commission's proposed rule mandating domestic, licensed reactors to convert to LEU fuel, however, would require domestic reactors to return unused HEU fuel and replace it with LEU fuel. This would require even those very low-power reactors with lifetime cores to return their present fuel and replace it with new LEU fuel. Although the proposed rule goes far beyond the requirements under consideration for overseas reactors, it would not directly affect the international traffic in HEU fuel because it applies only to domestic licensed reactors. Licensed reactors use only 10 percent of the HEU fuel used in U.S. research reactors. Thus, any indirect effect, such as setting an example for overseas reactors to follow, would appear to be quite limited.

POTENTIAL IMPACT

The potential impact of converting to LEU on the lower power reactors is primarily associated with costs and licensing problems rather than technological. In the case of high-performance reactors, however, the conversion to LEU would affect their productivity, efficiency of operation, and possibly their safety. As pointed out earlier, a great deal of effort and expense goes into optimizing the performance of these reactors because the highest quality and highest intensity neutron beams are required by the advanced research that is carried out. The conversion to LEU would decrease the beam intensities by 10 or 15 percent and increase the intensity of unwanted radiation by a similar amount. This would decrease the quality of the research beams by about 25 percent. This is a severe penalty to pay when the U.S. is already far behind our overseas competitors in this area of research which is so important to the development of advanced technologies. At one time, the U.S. was the world leader in research at nuclear reactors. Now we have fallen far behind our overseas competitors and should be directing our resources towards upgrading our research reactors. The requirement for new reactors to use LEU fuel would limit the design options and potential capabilities for major advances in the future.

The conversion to LEU would also adversely impact the efficiency of reactor operation. High-performance reactors use higher concentrations of uranium-235 in their fuel elements than is available in the recently developed LEU fuels. This so called "high loading" extends the life of the fuel elements and significantly reduces the cost of fueling the reactor. Even if the DOE efforts to develop LEU fuel that can provide the high loading required by high-performance reactors are successful, the fuel lifetime would be decreased because of the additional neutron absorbing material present, resulting in increased operating expenses.

The fuels under development by DOE to meet the higher loading required for high-performance reactors use very different materials than any that have been used previously. A few prototype elements may be tested extensively, but that testing is very limited compared to the thousands of HEU elements that have a demonstrated safety record over many years. It is unwise to mandate the conversion of high-performance reactors to fuels with such limited testing experience. High-performance reactors normally push their fuel to the safe limit as established by years of experience in the use of HEU fuel. The new fuels should be introduced gradually and voluntarily so engineering judgment can be exercised to determine their safe use rather than mandate their use in even the most demanding situations.

COST OF CONVERSION

The estimates, by DOE and the NRC, of the total cost of conversion of all university reactors vary from 8 to 15 million dollars if the proposed rule is adopted. If this cost were to be borne by the universities, many could not afford to continue operation; so, some type of federal assistance would be required. The cost estimates do not include the costs for reactors in the private sector nor for the NBS reactor. The cost of replacing the existing inventory of unused fuel including the cost of fabrication, shipping, and reprocessing would be about $2,000,000 for the NBS reactor alone, and the increase in its annual operating cost is estimated to be

$600,000. This, of course, does not include the loss in reactor productivity, and the resulting negative impact on U.S. scientific and technological capability.

SUMMARY

In summary, NBS sees no technological need to convert to LEU fuels--HEU fuels are technologically better. There appears to be little need to convert to LEU to further reduce the risk of domestic diversion of HEU, and the proposed domestic action will have little effect on the international traffic in HEU.

Conversion would adversely affect the productivity of high-performance reactors. For example, in the case of the NBS reactor, a 25 percent decrease in productivity is estimated. One time conversion costs would be significant, $2,000,000 for the NBS reactor alone, and annual operating costs would rise ($600,000 for the NBS reactor).

In order to regain a position of leadership in research reactor capability and improve U.S. competitiveness in many areas of advanced technology, it will be necessary to do everything possible to upgrade existing reactors and provide full flexibility for the design of advanced reactors. NBS believes the mandatory conversion to LEU fuels would severely limit the nation's options in achieving these objectives.

BIOGRAPHICAL DATA

ROBERT S. CARTER (Bob)
Chief, Reactor Radiation Division
National Bureau of Standards
Department of Commerce
Gaithersburg, MD 20899
(301) 921-2421

Princeton University (B.A. in Physics, 1948); Harvard University (M.A., 1949 and Ph.D., 1952). U.S. Navy 1944-46.

Associate Physicist at Brookhaven National Lab, 1952-56; Research in nuclear physics and lattice dynamics. Westinghouse Electric Corp. 1956-58, reactor physics and nuclear engineering.

Came to NBS 1958 as part of three-man group to develop a research reactor and associated scientific and technical programs to meet NBS needs. This included the conceptional and detailed design of the reactor as well as its procurement and supervision of construction. Directed neutron solid-state physics program.

Currently responsible for reactor operations, division technical programs, and the coordination of outside programs utilizing the reactor.

Professional Societies (Membership & Offices)

American Nuclear Society

American Physical Society

New York Academy of Sciences - Fellow

Committee Work

American National Standards Committee N-17, Research Reactors, Reactor Physics & Radiation Shielding - Chairman

American Nuclear Society Standards Steering Committee - Voting Member

Expertise

Solid State Physics:	Lattice Dynamics Molecular Dynamics Crystal Structure
Neutron Physics:	Neutron Scattering Neutron Cross Sections Neutron Standards
Nuclear Engineering:	Reactor Operation Reactor Physics Radiation Shielding

Mr. YOUNG. Thank you very much, Dr. Carter.

Mr. James J. McGovern, Union Carbide Corp. Mr. McGovern, your full statement will be made a part of the record and you can proceed, sir, in the manner you'd like.

STATEMENT OF JAMES J. McGOVERN, UNION CARBIDE CORP., MEDICAL PRODUCTS DIVISION

Mr. McGOVERN. Thank you, Mr. Chairman.

Union Carbide owns and operates a 5-megawatt nuclear research reactor that is located at the Sterling Forest Research Laboratory in Tuxedo, N.Y., and the activity conducted at this laboratory is primarily to produce radioisotopes for nuclear medicine. It's the only nuclear reactor serving this purpose in the United States today.

The conversion of this reactor to low-enriched fuel will have an adverse impact on the operating characteristics of this reactor for producing radioisotopes and other nuclear services that are currently provided.

This presentation is intended to highlight the importance of the continued operation of the Sterling Forest reactor, identify some major concerns about conversion to LEU and also describe some of the changes to the operating characteristics of the reactor core that will adversely impact the products and services that are now provided.

A brief description of the facility is in order. It's a 5-megawatt research reactor. It's light-water moderated and cooled. It is operating on a 95 percent duty cycle and it is fueled with 93 percent enriched aluminum alloy fuel. The laboratory, or the reactor, also contains five major hot cells with a capability of handling tens of thousands of curies of activity for production of medical isotopes.

The function of the facility is to produce radiochemicals in bulk form, produce radiopharmaceuticals in a finished drug product form and also to do neutron service irradiations in the reactor.

The products that come out of the facility are primarily molybdenum-99, xenon-133, iodine-131, iodine-125, molybdenum-technetium generators as drug products and reagent kits that are associated with the use of these generators, and NTD Silicon, which is an industrial use or application.

The Sterling Forest Laboratory in Tuxedo is a commercial venture which operates for profit. The reliable supply of shortlived radioisotopes is the essence of the industry. I would elaborate on that somewhat in that the isotopes that we provide are—are of half-lives or contain half-lives of days, 2.7 days, 5 days, on that order, which requires the continuous operation of the reactor. We can't shut down for prolonged periods and continue to supply these isotopes in the—on the scale that we are producing them today.

Some interesting statistics are that one in every four patients in a U.S. hospitals today benefit from a nuclear diagnostic procedure; 70 percent of all nuclear diagnostic procedures are performed with the isotope of technetium-99M. This is the daughter of molybdenum-99.

The product mix in the industry that we participate in—molybdenum-99 is the bulk of it, 80 percent of all isotopes, of all diagnostic tests are done with molybdenum. Xenon-133, iodine-131, iodine-125 and others represent the remainder.

The isotopes of molybdenum-99, xenon-133 and iodine-131 are separated from the fission products of U-235.

On the next page, in order to give a good appreciation of the impact on the public health of the Sterlings Forest Laboratory and its reactor is presented in that the tests that are performed in nuclear medicine are subdivided into two general categories: One would be in vivo testing, which is the process by which isotopes are injected into the blood stream of a person and images are enabled, through the use of the isotopes and also organ function can be determined, whether it's proper or improper function, can be determined by watching the behavior of the isotopes while they're in the body and approximately 5.2 million of these tests are done every year in the United States. About half of those are provided from isotopes that come from the Sterling Forest reactor.

The other major subcategory would be in vitro tests, whereby isotopes are combined with chemicals in a laboratory and they are then introduced into blood serum samples and by watching the behavior of these tagged compounds with the blood serum, very minute levels of constituents in the blood can be determined and this is an indication of diseased state. There are about 120 million of these tests done every year in the United States, and again, half of them are enabled by isotopes that come from the Sterling Forest reactor.

In looking at the prospect for converting to LEU fuel in the Sterling Forest reactor, we have two primary technical considerations: One would be the safety of the reactor operation. A lot has been said about that already. Briefly, as far as we're concerned, cladding integrity is of paramount importance. The cladding integrity, during normal service, as well as accident conditions, are very important. To date, I think some of the higher-density low-enriched fuels have demonstrated acceptable performance for normal operation. They have not been tested under postulated or actual accident conditions.

The other safety consideration revolves around the temperature of the fuel, the operating temperature, and in order to maintain that, you must maintain proper thermal hydraulic behavior in the core. You have got to have proper heat flux and sufficient cooling to take the heat away, so it's important when you convert from one type fuel to another that these parameters remain the same, or that proper adjustments are made to operating conditions to compensate for it.

The other major consideration that we have is the operating efficacy of the reactor. Will it be able to continue to perform its intended purpose and maintain the core characteristics that are—that control operating efficacy. These would be neutron energy spectrum, as someone has already mentioned here, and the thermal neutron flux level.

We see, from the demonstrations to date, that there will be a reduction in the thermal neutron flux level which will lead to lower operating efficiency, and right now, we can estimate it to be about 10 percent. We will lose 10 percent operating efficiency.

The neutron quality or the neutron spectrum or the relative distribution of neutron energies will change and we can see it hardening from experience and predictions that have been made to date, which will have an adverse effect on the isotope production as well.

Our primary isotope production method is the fissioning of uranium and then extracting fission products. Well, if you have a hardened spectrum, your number of fission products and transuranics change. With the high-enriched fuel that we have in the reactor now, we have this very well qualified. We have a very good handle on this. If we use low-enriched fuel, it will require a research program to get another handle on it.

Another aspect that we have to look at is financial considerations. The costs have already been mentioned. In our case, we are looking at a relicensing cost, probably man-years of work; we are looking at new fuel—fabrication costs will probably change. The best estimate that we have now is probably a 15-percent increase in the fabrication cost of fuel.

We'll have installation costs and that will depend upon whether we can change the core incrementally or we have to shut down to change the core over instantaneously.

If we cannot get extra burn-up out of these more costly fuel assemblies, it will cost us more to operate the reactor so we would want to get more fuel life out of a low-enriched fuel. Then we have the reprocessing cost, which could change, probably will change because of the changed fuel, but we don't have any estimate of what that will be.

In summary, as far as cost is concerned, we can see the reduced thermal flux increasing our variable operating cost by 10 percent and this could amount to several hundred thousand dollars per year to us.

The hardened neutron spectrum will increase the transuranic production in isotope target waste. This will have a major impact on the waste disposal costs at the facility and if it's severe enough, it could put us out of business.

Another minor aspect of a hardened flux will be that it will have an effect on a product that we produce, which is called NTD Si. Now, we're not sure if we will be able to continue that.

The next page is entitled "Choice of Fuel." In essence, what we have concluded from the suggested fuel designs that are available to date, we will—if we wanted to try to maintain operating efficiency and to try to maintain the quality of the neutron flux in the core, we are limited to the higher density fuels with the approximate same metal-to-water ratios that we have in our core right now, and we're talking about the higher densities in the area of 4.8 grams per cubic centimeter to 6 grams per cubic centimeter.

The licensing implications are that we will have to revise the technical specifications for the reactor. Most—a recent experience with that, we are under license renewal proceedings right now. We have been working on this for 4 years, so this is no small task. We will have to revise the safety analysis report. A major license change is in order—I think you could—you would have to categorize this as a major license change. Current regulations require that an environmental impact assessment be done again and this would open the door for more public hearings and we don't welcome this.

As far as implementation is concerned, if we had our choice, we would not—we would like to not have to implement this. If we did, we would have to use the higher density fuels and we're talking about the latter part of this decade.

In summary, if conversion to LEU fuel becomes mandatory, the Union Carbide reactor at Sterling Forest would have to convert to the high-density fuels. Conversion would have to be gradual or incremental, rather than instantaneous. The operating costs will rise and we believe at this point, it could be as much as 20 percent. There will be man-years of technical staff work that would be required to revise tech specs. SAR's, operating procedures as a result of changed SAR's, and training material.

The operating characteristics of the reactor will change. The operating constants will change and people will have to be retrained in being able to operate the reactor.

The question remains whether the conversion of the UCNR will be subsidized. This is a commercial enterprise. Development of higher density fuels with high-enriched uranium had offered the promise heretofore of higher operating efficiency and productivity. This advantage is negated by the mandate to go to low-enriched uranium.

We still have a question as to whether these suggested benefits of the LEU conversion are worth the apparent effort and expense involved in converting.

Thank you, Mr. Chairman.

[The prepared statement of Mr. McGovern follows:]

UNION CARBIDE

UNION CARBIDE CORPORATION • [illegible] NEW YORK [illegible]
MEDICAL PRODUCTS DIVISION
[illegible]

SEPTEMBER 21, 1984

PRESENTATION TO: U. S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515

SUBJECT: CONVERSION OF THE UNION CARBIDE CORPORATION NUCLEAR RESEARCH REACTOR FROM HIGH ENRICHED URANIUM (HEU) TO LOW ENRICHED URANIUM (LEU).

INTRODUCTION:

UNION CARBIDE OWNS AND OPERATES A 5 MW NUCLEAR RESEARCH REACTOR THAT IS LOCATED AT THE STERLING FOREST RESEARCH LAB PRIMARILY TO PRODUCE RADIOISOTOPES FOR NUCLEAR MEDICINE. IT IS THE ONLY NUCLEAR REACTOR SERVING THIS PURPOSE IN THE USA. THE CONVERSION OF THIS REACTOR TO LOW ENRICHED FUEL WILL HAVE AN ADVERSE IMPACT ON THE OPERATING CHARACTERISTICS OF THIS REACTOR FOR PRODUCING RADIOISOTOPES AND OTHER NUCLEAR SERVICES THAT ARE CURRENTLY PROVIDED.

THIS PRESENTATION IS INTENDED TO HIGHLIGHT THE IMPORTANCE OF THE CONTINUED OPERATION OF THE STERLING FOREST REACTOR, IDENTIFY SOME MAJOR CONCERNS ABOUT THE CONVERSION TO LEU, AND ALSO DESCRIBE SOME OF THE CHANGES TO THE OPERATING CHARACTERISTICS OF THE REACTOR CORE THAT WILL ADVERSELY IMPACT THE PRODUCTS AND SERVICES THAT ARE NOW PROVIDED.

UNION CARBIDE NUCLEAR REACTOR

Tuxedo, New York

RESEARCH REACTOR

5 Mw Power

Light Water Moderated & Cooled

Approximately 95% Duty Cycle

Uranium-Aluminum Fuel (93% U-235)

HOT LABORATORY

5 Major Hot Cells

50,000 Ci Elements Z, 3-83

60% Duty Cycle

FUNCTION

Produce Radiochemicals

Produce Radiopharmacueticals

Neutron Service Irradiations

PRODUCTS

Mo-99, Xe-133, I-131, I-125, etc.

Mo-99/Tc-99m Generators, Tc Diagnostic Reagent Kits

NTD Si, etc.

REACTOR BASED
RADIOCHEMICAL PRODUCERS
WORLD MARKET

The Sterling Forest Laboratory in Tuxedo is a commercial venture which operates for profit.

Reliable supply of shortlived radioisotopes is the essence of the industry. One in every four patients in U.S. hospitals benefits from a nuclear diagnostic procedure. 70 percent of all nuclear diagnostic procedures are performed with the Tc-99m isotope, the daughter of Mo-99.

Product Mix:

Mo-99 (Fission Process)	80%
Xe-133	5%
I-131	5%
I-125	5%
Others	5%

The isotopes of Mo-99, Xe-133 and I-131 are separated from the fission products of U-235.

Producers (F.P. Mo-99):

Union Carbide Corporation (UCC)	45%
Atomic Energy of Canada Ltd. (AECL)	45%
I.R.E. Belgium (IRE)	5%
Australian Atomic Energy Commission (AAEC)	5%

AECL, IRE, and AAEC are government subsidized enterprises.

UNION CARBIDE. NUCLEAR PRODUCTS

IMPACT ON PUBLIC HEALTH

NUCLEAR MEDICINE (IN VIVO TESTS)

TYPE OF TEST	TOTAL 1981 TEST PROCEDURES	% UCC CONTRIBUTES
LUNG INHALATION	320.000	30%
LIVER	1.425.000	50%
BONE HMDP	1.6L5.000	50%
BLOOD POOL	100.000	50%
KIDNEY	456.000	50%
LUNG PERFUSION	775.000	50%
BRAIN/THYROID	500.000	50%
TOTAL	5.181.000	2.500.000

RADIOMMUNOASSAY (IN VITRO TESTS)

THYROID HORMONES	48.000.000	50%
DIGOXIN	14.000.000	50%
HUMAN CHORIONIC GONADOTROPIN	11.000.000	50%
B-12/FOLATE	6.000.000	50%
I GE IMMUNE TEST	6.000.000	50%
CORTISOL	4.000.000	50%
ESTRIOL	4.000.000	50%
ANGIOTENSIN	1.500.000	50%
DIGITOXIN	1.400.000	50%
METHOTREXATE	120.000	50%
OTHERS	25.000.000	50%
TOTAL	120.000.000	60.000.000

LEU CONVERSION

TECHNICAL CONSIDERATIONS

OPERATING SAFETY:

Cladding Integrity

(a) Normal Service

(b) Accident Conditions

The low density, high enriched fuels have been proven to be reliable in normal service and under accident conditions. They have proven reliable in approximately 30 years of normal operation and also under accident conditions demonstrated in the SPERT and BORAX tests.

Performance of the high density, low enriched fuels can be modeled fairly well in computer codes however behavior under accident conditions may not be as predictable without some empirical data.

Thermal Hydraulic Behavior

(a) Heat Flux

(b) Coolant Channel Dimensions

It is important to maintain the same thermal hydraulic behavior to avoid major cooling system changes.

OPERATING EFFICACY:

Neutron Energy Spectrum

Thermal Neutron Flux Level

The UCNR operates primarily for producing radioisotopes and performing service irradiations commercially. The Ford Reactor conversion to LEU resulted in a hardened neutron flux spectrum and a reduction in the thermal neutron flux. These changes will have serious consequences in the UCNR operation.

LEU CONVERSION

FINANCIAL CONSIDERATIONS

COST OF REACTOR CONVERSION:

RELICENSING COST (MAN YEARS OF WORK)

FUEL FABRICATION COST (U_O, ALUMINIDE, SILICIDE)
LAST ESTIMATED TO INCREASE 15 PERCENT

INSTALLATION COST (INCREMENTAL VS INSTANTANEOUS CHANGE)

FUEL LIFE (PERCENT BURN-UP AND INITIAL LOADING)

REPROCESSING COST (NO DATA AVAILABLE)

COST OF ISOTOPE PRODUCTION:

REDUCED THERMAL FLUX WILL INCREASE VARIABLE OPERATING COST PROPORTIONATELY. (IF VARIABLE COST OF ISOTOPE PRODUCTION IS SEVERAL MILLION DOLLARS THEN A 10 PERCENT REDUCTION IN THERMAL NEUTRON FLUX WILL CAUSE INCREASED OPERATING EXPENSE OF SEVERAL HUNDRED THOUSAND DOLLARS.)

HARDENED FLUX WILL INCREASE TRANSURANIC PRODUCTION IN ISOTOPE TARGET WASTE. (THIS WILL ADD A SUBSTANTIAL COST IN WASTE DISPOSAL. IT MAY PRECLUDE OUR USING COMMERCIAL LLW BURIAL SITES.)

HARDENED FLUX WILL INCREASE FAST NEUTRON DAMAGE IN NTD SI.

CHOICE OF LEU FUEL

If LEU conversion is required, it will be most desirable to maintain neutron flux level and energy spectrum and also to yield operating economies that will compensate for the conversion expense as much as possible. Some basic LEU fuel designs are presented in the following table.

LEU FUEL LOADINGS
(gms U-235)

		Design Number and # of Plates & Meat Width (mm)				
Type	U Density gm/cm^3	1 16/.51	2 18/.51	3 17/.76	4 16/1.0	
U_3O_8 or U_3Si_2	2.3	-	-	222	276	> Current Cost
U_3O_8 or U_3Si_2	3.2	196	220	310	383	↑
U_3Si_2	4.0	244	275	387	479	↓
U_3Si_2	4.8	293	330	464	575	< Current Cost
U_3Si_2	6.0	367	412	580	719	
		≃ Metal/H_2O ←		→ > Metal/H_2O		

THE FUEL DESIGNS APPEARING IN THE LOWER LEFT QUADRANT PROVIDE THE NEUTRON SPECTRUM AND OPERATING ECONOMY THAT IS SIMILAR TO CURRENT EXPERIENCE. THEY MAY ALSO ALLOW CONTINUED OPERATION THROUGHOUT THE CONVERSION PROCESS.

LICENSING

REVISE TECHNICAL SPECIFICATIONS:

(AT LEAST 2 MAN YEARS UCC & NRC)

REVISE SAR:

(RENEWAL OF PRESENT LICENSE STARTED 1980 AND RENEWAL IS EXPECTED IN 1984.)

MAJOR LICENSE CHANGE:

(PUBLIC HEARING AND EIA)

WE AGREE WITH THE CONCERNS OF THE UNIVERSITY REACTOR COMMUNITY ABOUT THE SUBSTANTIAL EXPENSE INVOLVED IN THE LICENSE RENEWAL PROCESS THAT WILL BE REQUIRED IN LEU CONVERSION.

IMPLEMENTATION

ROUTINE OPERATION MUST NOT BE INTERRUPTED.

WILL NEED U_3Si_2 FUEL WITH HIGH LOADING DENSITY (1986).

LICENSE 1988

INSTALL INCREMENTALLY 1989 - 1990.

SUMMARY

IF CONVERSION TO LEU FUEL BECOMES MANDATORY:

(A) CONVERSION OF UCNR MUST BE WITH U_3SI_2 OR U_3 SI

(B) CONVERSION MUST BE GRADUAL OR INCREMENTAL.

(C) OPERATING COST WILL RISE. (CURRENT ESTIMATE IS 20%). WE ARE UNCERTAIN ABOUT HOW THIS DISADVANTAGE RELATIVE TO COMPETITORS CAN BE OVERCOME.

(D) MAN YEARS OF TECHNICAL STAFF (UCC AND NRC) WORK WILL BE REQUIRED TO REVISE TECHNICAL SPECIFICATIONS, SAR'S, OPERATING PROCEDURES AND TRAINING MATERIAL.

(E) THE QUESTION REMAINS OF WHETHER THE CONVERSION OF THE UCNR WILL BE SUBSIDIZED.

(F) DEVELOPMENT OF HIGHER DENSITY FUELS (WITH HEU) HAD OFFERED THE PROMISE OF HIGHER OPERATING EFFICIENCY AND PRODUCTIVITY. THIS ADVANTAGE WILL BE NEGATED WITH LEU.

(G) ARE THE SUGGESTED BENEFITS OF LEU CONVERSION WORTH THE APPARENT EFFORT AND EXPENSE?

Mr. Young. Thank you very much, Mr. McGovern.

Our next witness will be Francis DiMeglio, National Organization of Test Research and Training Reactors, Rhode Island Nuclear Science.

As with the other witnesses, your full statement will be made a part of the record and, sir, you can go ahead and proceed to summarize the way you'd like.

STATEMENT OF DR. A FRANCIS DiMEGLIO, CHAIRMAN, NATIONAL ORGANIZATION OF TEST, RESEARCH AND TRAINING REACTORS, AND DIRECTOR, RHODE ISLAND NUCLEAR SCIENCE CENTER

Dr. DiMeglio. Thank you, Mr. Chairman.

I'm here today as the chairman of the National Organization of Test Research and Training Reactors, which appreciates the opportunity to present its views before these subcommittees.

The 31 or so nonpower reactors which are affected by the proposal to convert fuel elements from HEU to LEU are all members of TRTR. While this group of reactors is sometimes thought of as university reactors, in fact, it contains reactors operated by the Federal Government and by private industry.

TRTR conducted its annual meeting in August of this year and many of my remarks are from the consensus developed at that meeting.

The operators of the 31 affected reactors fully support the goals of no undue risk of diversion of enriched uranium from their facilities. However, they do not believe that the achievement of acceptable risks requires the abandonment of the use of HEU's, which is what the NRC proposed rule ultimately will require.

In the United States, there are 36 Department of Energy research and test reactors, 3 reactors of other Government agencies, 25 university reactors and 5 private reactors which utilize HEU fuel. Of these reactors, the Government-owned, mostly DOE reactors, account for about 90 percent of the HEU in current use.

This conversion of the 31 targeted nonpower reactors only involves about 10 percent of the HEU currently in use in domestic nonpower reactors. In addition, the conversion of these reactors does not materially affect the existing residual risks associated with the nearly 20 tons of HEU fuel already exported.

Dr. Zebroski has qualitatively examined the relative diversion risk for many different types of facilities and, as he showed us earlier, he concludes that the nonpower reactors under consideration present the lowest diversion exposure, thus the conversion of these 31 reactors to low-enriched uranium does not significantly affect either the domestic or international diversion risk.

Earlier this afternoon, Commissioner Bernthal spoke about reducing the diversion risk by these conversions. Dr. Zebroski pointed out that when Commissioner Bernthal talks about reducing the risk, what he really said was reducing the risk all the way to zero.

TRTR also believes that this is true and that the conversion proposal under consideration has as its goal the reduction to zero of the diversion risk of any amount, however small, of domestic HEU. TRTR further believes that the goal should be the reduction to an acceptable level of the diversion risk of significant quantities of HEU.

In TRTR's view, these differences are extremely important because these differences are the reasons why alternatives to HEU abandonment have not been considered as means of achieving acceptable risk. The only way you can ever get to zero risk is obviously to remove all the HEU.

TRTR believes that the risks of significant diversion could be made acceptable by means of appropriate security and by engineering fixes such as long-life cores. In many facilities, these conditions already exist and can be extended to additional facilities. For example, there is some appropriate level of security which makes the risk of diversion acceptably small. TRTR believes that such security already exists since the security plans for most facilities were evaluated by the NRC against a diversion risk within the last few years and approved.

There are several facilities which have lifetime cores with less than 5 kilograms of fuel in the entire facility. With the new fuel technology, it's possible to fabricate long-life cores—certainly not lifetime—for other reactors, allowing them to operate with HEU inventories approaching 5 kilograms. Because of the longer lifetime of such fuel, fewer elements will be in the fabrication pipeline and in transit, thereby reducing the proliferation risk in comparison with today's practices.

Another reason given for the conversion of these 31 nonpower reactors to LEU is to set an example for the operators of foreign reactors. TRTR believes that the example being set is the conversion of the U.S. lowest power reactors involving a very small amount of domestic HEU. In other words, we believe that it's a token type of example.

In this regard, I recently received a copy of a letter from Peter von der Hardt to the Nuclear Regulatory Commission expressing his personal concerns about the U.S. proposal. Dr. von der Hardt is chairman of the European version of TRTR.

In his letter, he states:

> The proposed rule specifically refers to non-U.S. reactors and to the encouragement to conversion that should be achieved. It is limited, however, to medium- and low-power reactors of 5 megawatt maximum power—with the exception of Missouri and the National Bureau of Standards reactor. Large test reactors at National Laboratories are not concerned. The impact on overseas reactors should therefore also be limited to installations below 5 megawatts which, as in the United States, consume only a minor fraction of the total HEU in circulation.

He concludes that:

> In conclusion, as far as the impact on European reactors is concerned, the following comments can be formulated. In view of the remaining technical and economic uncertainties, the statement "the reduction in domestic-use HEU fuel may encourage similar action by foreign research reactor operators" appears to be premature. Large differences exist between different European research reactors in terms of their designs, modes of operation and utilization, and political environments. Case-by-case convertibility assessment is therefore required; and third, although the ORR is implied through the planned whole-core silicide fuel demonstration, other large DOE reactors are not concerned by the proposed rule. This weakens the case of demonstrating good will to the outside world.

Concerning need, then, TRTR believes that based on the existing acceptable low risks, the existence of alternatives and the lack of a proper example, the proposed conversions are unnecessary and should not take place.

Addressing impacts, then, the potential impact of LEU conversion to university nuclear engineering departments will be discussed by Dr. Turinsky and I'll not speak to this point.

This impact, however, has also been discussed by the American Nuclear Society, whose board of directors authorized the transmittal of three letters to the Nuclear Regulatory Commission on this and other points. These letters are attached for the record.

Instead, I'd like to speak to the impact on the reactors themselves. In all cases, conversion to LEU will result in about a 10-percent decrease in the available thermal neutron flux from the reactor. This has been brushed aside as not too important and for a high-powered research reactor, or a low-powered training reactor, this is probably correct. However, for the intermediate-power reactor, say 2 megawatts, a 10-percent decrease, especially if it's accompanied by a 15-percent shift in spectrum, can be serious.

For example, the neutron spectroscopy group at the Rhode Island Nuclear Science Center has recently spent 2 years designing and building new beam port plugs which, through special techniques, will increase the flux available for their experiment by 10 percent. If you now convert the reactor to low-enriched uranium, this gain is wiped out.

More importantly, forced conversion will most certainly result in shutting down several facilities, even if the Federal Government pays for the low-enriched uranium fuel, for shipping of spent fuel, and for facility modifications. We believe there are two reasons for this: First, administrators, or especially university administrators, view low-enriched uranium as just another Nuclear Regulatory Commission requirement in a long list of recent new requirements which eat up university funds. If they are now required to remove the existing fuel, then following the removal of this fuel, just decommission the facility and end the continuing problem.

Second, these administrators, in spite of the talk of generic licensing for LEU, look at existing Nuclear Regulatory Commission rules and regulations and see the possibility of protracted licensing problems involving large sums of money with uncertain results. The entire nonpower reactor community has been sensitized to the licensing issue because of the recent decision of UCLA to withdraw its application for license renewal and decommission its facility after 4 years of relicensing hearings, at an estimated cost to UCLA of $500,000.

There are few facilities which could afford such legal expenses. This situation was recognized by the ACRS in its report and it was presented here again this morning in its report—this afternoon, in its report to the Nuclear Regulatory Commission which stated:

> If, as a consequence of changes needed to affect a conversion, a license amendment is required—and most facility operators believe that somewhere there will be a license amendment required—then a hearing with the opportunity for public intervention is possible. Before the Commission adopts a rule which might permit unrestricted intervention, we recommend that the Commission obtain an evaluation of the course, nature, costs and other relevant aspects of previous contested hearings involving nonpower reactors to determine if the hearings are serving their intended function effectively.

It may be that the rules regarding hearings involving low-power research reactors should be different than those for power reactors.

Before leaving the topic of potential impact, I should point out that the proposed rule is not clear on the funding for a conversion of those reactors operated by private industry.

I'd like to now in addition by discussing the Department of Energy Research and Development Program on Low-Enriched Fuel.

In the late 1970's, when TRTR first learned of the possibility of converting nonpower reactors to low-enriched uranium, its communications with the NRC stressed the unavailability of the required fuel. At that time, the Department of Energy estimated a 2-year, $10 million program. Of course, the program has spent about $35 million and it's estimated that the program will use about another $30 million over the next 6 years. Conversion of reactors is estimated at between $12 and $15 million.

None of these figures include what the NRC and individual facilities have spent and do not include funds for relicensing. These figures also don't include, obviously, the societal costs if some of these reactors end up decommissioning because of the LEU situation.

Now, I know the $76 million may not seem like a large amount of money in this room, but in terms of nonpower reactors, it's sufficient to keep almost all of these reactors operating for a very, very long time. From this development program has come fuel suitable for intermediate power reactors with one shortcoming: These fuels have not been subjected to the testing under abnormal accident conditions as the existing fuels have, and in addition, these fuels do not have the operating history generated by the existing fuels in national laboratories before being placed in a university environment.

With regard to funding, if conversions are mandated by the NRC, then TRTR believes that such conversions will be based on a change in national policy, rather than on some unidentified threat. All conversions should be a Federal Government expense for all reactors operated by non-Federal Government organizations.

In addition to the direct costs for the new fuel, reprocessing of old fuel and facility modifications, these Federal funds should be available for relicensing, including litigation and for lost overhead funds for the facility staff involved in the relicensing procedure.

[The prepared statement of Dr. DiMeglio follows:]

PRESENTATION BEFORE

HOUSE OF REPRESENTATIVES
SUBCOMMITTEES ON

ENERGY DEVELOPMENT AND APPLICATIONS
ENERGY RESEARCH AND PRODUCTION

BY

A. FRANCIS DI MEGLIO
CHAIRMAN
NATIONAL ORGANIZATION OF TEST, RESEARCH AND TRAINING REACTORS

ON

CONVERSION OF DOMESTIC RESEARCH AND TEST
REACTORS TO LOW ENRICHED URANIUM
(LEU) FUEL

SEPTEMBER 25, 1984

The National Organization of Test, Research and Training Reactors (TRTR) appreciates the opportunity to present its views before these subcommittees. The 31 or so non-power reactors which are affected by the proposal to convert fuel elements from high enriched uranium (HEU) to low enriched uranium (LEU) are all members of TRTR. While this group of reactors is sometimes thought of as university reactors, in fact, it contains reactors operated by the federal government and private industry.

TRTR conducted its annual meeting in August, 1984 and many of my remarks are from the concensus developed at that meeting.

The operators of the 31 affected reactors fully support the goals of no undue risk of diversion of enriched uranium from their facilities. However, they do not believe that the achievement of acceptable risk requires the abandonment of the use of HEU, which is what the Nuclear Regulatory Commission proposed rule ultimately will require.

In the United States, there are 36 Department of Energy research and test reactors, 3 reactors of other government agencies, 25 university reactors and 5 private reactors which utilize HEU fuel. Of these reactors, the government owned, mostly Department of Energy reactors, account for about 90% of the HEU in current use (1). This conversion of the 31 targeted non-power reactors only involves about 10% of the HEU currently in use in domestic non-power reactors. In addition, the conversion of these reactors does not materially affect the existing residual risks associated with the nearly 20 tons of HEU fuel already exported. Zebroski (2) has qualitatively examined the relative diversion risks from many different types of facilities and he concludes that the non-power reactors under consideration present the lowest diversion exposure. Thus, the conversion of these 31 reactors to LEU does not significantly affect either the domestic or international diversion risk.

TRTR believes that the conversion proposal under consideration has as its goals the reduction to zero of the diversion risk of any amount, however small, of domestic HEU. TRTR further believes that the goal should be the reduction to an acceptable level of the diversion risk of significant quantities of HEU. In TRTR's view, these differences are the reason why alternatives to HEU abandonment have not been considered as means of achieving acceptable risk.

TRTR believes that the risks of significant diversion can be made acceptable by means of appropriate security and by engineering fixes such as long-life cores. In many facilities, these conditions already exist and can be extended to additional facilities. For example, there is some appropriate level of security which makes the risk of diversion acceptably small and TRTR believes that such security already exists since the security plans for most facilities were evaluated by the Nuclear Regulatory Commission against a diversion risk within the last few years and approved. There are several facilities which have lifetime cores with less than 5 kg of fuel in the entire facility. With the new fuel technology, it is possible to fabricate long-life cores, not lifetime, for other reactors allowing them to operate with HEU inventories approaching 5 kg. Because of the longer lifetime of such fuel, fewer elements will be in the fabrication pipeline and in transit, thereby reducing the proliferation risk in comparison with today's practices.

Another reason given for the conversion of these 31 non-power reactors to LEU is to set an example for the operators of foreign reactors. TRTR believes that the example being set is the conversion of the United States's lowest power reactors involving a very small amount of domestic HEU. In this regard, I recently received a copy of a letter from Peter von der Hardt to the Nuclear Regulatory Commission expressing his personal concerns about the United States proposal. (Incidently, Dr. von der Hardt is chairman of the European TRTR which is currently being organized.) In his letter he states (3):

> "The proposed rule specifically refers to non-United States reactors and to the encouragement to conversion that should be achieved. It is limited, however, to medium and low power reactors of 5 MW maximum power (with the exception of MURR and NBSR). Large test reactors at National Laboratories are not concerned. The impact on overseas reactors would therefore be limited to installations below 5 MW which, as in the United States, consume only a minor fraction of the total HEU in circulation."

He concludes:

> "In conclusion, as far as the impact on European reactors is concerned, the following comments can be formulated:

1. In view of the remaining technical and economic uncertainties the statement "the reduction in domestic use HEU fuel may encourage similar action by foreign research reactor operators, ..." appears to be premature.
2. Large differences exist between different European research reactors in terms of their designs, modes of operation and utilization, and political environments. Case-by-case convertibility assessment is therefore required.
3. Although the ORR is implied through the planned whole core silicide fuel demonstration, other large DOE reactors are not concerned by the proposed rule. This weakens the case of demonstrating "good will" to the outside world."

Concerning need, then, TRTR believes that based on the existing acceptable low risks, the existence of alternatives and the lack of a proper example, the proposed conversions are unnecessary and should not take place.

The potential impact of LEU conversion to university nuclear engineering departments will be (has been) discussed by Dr. Turinsky and I will not speak to this point. This impact has also been discussed by the ANS whose Board of Directors authorized the transmittal of three letters (3) to the Nuclear Regulatory Commission on this and other points. Instead, I would like to speak to the impact on the reactors themselves. In all cases, conversion to LEU will result in about a 10% decrease in the available thermal neutron flux from the reactor. This has been brushed aside as not too important and for a high-powered research reactor or a low-power training reactor, this is probably correct. However, for the intermediate power reactor, say 2 MW, a 10% decrease can be serious. For example, the neutron spectroscopy group at the Rhode Island Nuclear Science Center has recently spent two years designing and building new beam port plugs which, through special techniques, will increase the flux available for their experiment by 10%. Conversion to LEU wipes out this gain.

More importanly, forced conversion will most certainly result in shutting down several facilities, even if the federal government pays for the LEU fuel, for shipping of spent fuel, and for facility modifications. There are two reasons for this. Firstly, administrators, especially university administrators, view LEU as just another Nuclear Regulatory Commission requirement in a long list of recent new requirements which eat up university funds. If they are now required to remove the existing fuel, then, at this point, decommission and end the continuing problem. Secondly, these administrators, in spite of the talk of generic licensing for LEU, look at existing Nuclear Regulatory Commission rules and regulations and see the possibility of protracted licensing problems involving large sums of money with uncertain results. The entire non-power reactor community has been sensitized to the licensing issue because of the recent decision of UCLA to withdraw its application for license renewal and decommission its facility after four years of relicensing hearings at an estimated cost to UCLA of $500,000. There are few facilities which could afford such legal expenses. This situation was recognized by the ACRS in its report (3) to the Nuclear Regulatory Commission which stated:

> "If, as a consequence of changes needed to effect a conversion, a license amendment is required, then a hearing with the opportunity for public intervention is possible. Before the Commission adopts a rule which might permit unrestricted intervention, we recommend that the Commission obtain an evaluation of the course, nature, costs, and other relevant aspects of previous contested hearings involving nonpower reactors to determine if the hearings are serving their intended function effectively. It may be that the rules regarding hearings involving low power research reactors should be different than those for power reactors."

Before leaving the topic of potential impact, I should point out that the proposed rule is not clear on the funding for a conversion of those reactors operated by private industry. Although the proposed rule does not make a distinction between university and industrially operated reactors, it is not clear that the federal government will pay for the conversion of reactors operated by industrial organizations.

I would now like to discuss the Department of Energy Research and Development Program on LEU Fuel.

In the late 70's, when TRTR first learned of the possibility of converting non-power reactors to LEU, its communications with the Nuclear Regulatory Commission stressed the unavailability of the required fuel. At that time, the Department of Energy estimated a two-year, 10 million dollar program. In fact, the program has spent about 35 million dollars and it is estimated that the program will use about another 30 million dollars. Conversion of reactors is estimated at between 12 and 15 million dollars. None of these figures include what the Nuclear Regulatory Commission and individual facilities have spent and do not include funds for relicensing. Now, I know that 76 million dollars may not seem a large amount of money, but in terms of non-power reactors, it is sufficient to keep almost all of these reactors operating for a very long time.

From this development program has come fuel suitable for intermediate power reactors with one shortcoming. These fuels have not been subjected to the testing under abnormal, accident conditions as the existing fuels have, and, in addition, these new fuels do not have the operating history generated by the existing fuels in National Laboratories before being placed in a university environment.

With regard to funding if conversions are mandated by the Nuclear Regulatory Commission, TRTR believes that since conversions will be based on a change in National policy rather than on some unidentified threat, all conversions should be at federal government expense for all reactors operated by non-federal government organizations. In addition to the direct costs for the new fuel, reprocessing of old fuel and facility modifications, these federal funds should be available for relicensing, including litigation and for lost overhead funds for the facility staff envolved in the relicensing procedure.

REFERENCES

(1) Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel, NUREG/CR-3666, February, 1984.

(2) Relative Diversion Exposures of High Enrichment Uranium: Relation to University Research Reactors, Edwin L. Zebroski, EPRI, Presented at ANS Meeting, New Orleans, June 4, 1984

(3) Copy of letter attached.

Commission of the European Communities

JOINT
RESEARCH
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AIR
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The Secretary of the Commission
U.S. Nuclear Regulatory Commission
WASHINGTON, DC 20555
USA

Attention: Docketing and Service Branch

Petten, August 31, 1984
PvdH/npr-82.684

Gentlemen,

Federal Register, Vol. 49, No. 131
Proposed Rule "Limiting the Use of Highly Enriched
Uranium in Domestic Research and Test Reactors."

Enclosed comments do not refer to the Proposed Rule as such since that would be beyond my formal and professional competence.

I merely wish to express ideas about the possible impact of the Rule on the attitudes of European non-power reactor operators.

Please note that the enclosed notes reflect my personal ideas and do by no means commit the European Communities.

Sincerely,

v. der Hardt

P. von der HARDT
Head, HFR Division

ENCL.

Federal Register, 49, No 131, 27769-27772 (July 6, 1984)
Proposed NRC Rule
"Limiting the Use of Highly Enriched Uranium
in Domestic Research and Test Reactors"

Pvdll/npr-82.684

Personal Comments

A. There is full agreement on the basic necessity and principles of nuclear non-proliferation.

The recommendations of INFCE Working Group 8C have been taken seriously in Europe, and several countries operate government-funded programs for studying research and prototype reactor conversion to reduced enrichment fuel. A number of organisations have entered into collaboration agreements with the DOE RERTR Program. A whole core LEU conversion of a 70 MW test reactor has been demonstrated by the French CEA since several years.

B. The larger European test reactors have implemented physical security systems in accordance with IAEA recommendations. A specially designed high security vehicle is used for road transports of unirradiated HEU. Administrative and physical checks of HEU inventories and movements take place regularly by Euratom and IAEA inspectors.

C. Pressure on European research reactor operators to convert to low enriched fuel is exerted by US Government agencies during the review process of export license requests. Since 1983 the demands for HEU export licenses have to be supported by a questionnaire with details on the reactor's fuel cycle and on its operator's involvment in conversion studies, and by a conversion time schedule. The pressure exerted seems to vary from tough ("This was your last export license") to soft or non-existing.

D. The proposed rule specifically refers to non-US reactors and to the encouragement to conversion that should be achieved. It is limited, however, to medium and low power reactors of 5 MW maximum power (with the exception of MURR and NBSR). Large test reactors in National Laboratories are not concerned. The impact on overseas reactors would therefore be limited to installations below 5 MW which, as in the US, consume only a minor fraction of the total HEU in circulation.

E. There are moreover a number of questions to which no satisfactory answers are available to date:

1. fuel performance: Only LEU fuel up to 3 g U/cm^3 for low to medium power reactors has been sufficiently qualified. Another step forward is expected for 1985/86 with the whole core experiment in ORR on 4,8 g U/cm^3 silicide fuel. Higher density silicide fuel, required for high flux/high power reactors, will not be commercially qualified before 1987/88.

2. core physics: Reducing the enrichment from 93% to 20% implies, which ever the fuel type, adding ten or more kg of ^{238}U to the reactor core. Core physics studies have shown that this is feasible, with satisfactory reactivity development through core lifetime. On the other hand, there is marginal loss of fast and substantial loss of thermal neutron flux. A number of experimental applications of research reactors are hit by such development, and solutions need to be found to overcome this problem.

   As for cost analyses and licensing aspects, however, generic studies of core physics (and possibly, thermohydraulics) cannot supply the information needed by the individual reactor operator. Case-by-case analysis is required.

3. fuel cycle: US Government statements are missing on the following issues:

   a) swift handling of future LEU export licenses

   b) reprocessing of LEU fuel elements

   c) the price of reprocessing, and the residual fissile material credits

   d) guaranteed civil use by the US of the returned material.

4. cost: The two issues are conversion expenses and the increase of the annual fuel cycle cost.

Conversion expenses cover studies, calculations, fuel element design and testing, plant modifications, licensing, and possible losses on the last HEU elements. They are partially covered by Government-funded programs but estimations on their final amounts are not available.

Studies on annual LEU vs. HEU fuel cycle costs have recently been initiated. Although still hampered by uncertainties of reprocessing and fuel element manufacture cost, the following estimation is presently possible

Cost item	Estimated LEU vs. HEU fuel cycle cost increase /%/
Uranium mass in circulation	10
Reprocessing	0 to 20
Fuel element manufacture	10 to 40
Reactor power increase (compensating loss of neutron flux)	5 to 10
TOTAL	25 to 80 %

F. In conclusion, as far as the impact on European reactors is concerned, the following comments can be formulated:

1. In view of the remaining technical and economic uncertainties the statement "The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, ..." appears to be premature.

2. Large differences exist between different European research reactors in terms of their designs, modes of operation and utilization, and political environments. Case-by-case convertibility assessment is therefore required.

3. Although the ORR is implied through the planned whole core silicide fuel demonstration, other large DOE reactors are not concerned by the proposed rule. This weakens the case of demonstrating "good will" to the outside world.

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March 19, 1984

Dr. Nunzio J. Palladino, Chairman
U.S. Nuclear Regulatory Commission
Washington, DC

Dear Dr. Palladino:

Conversion of Fuel Elements of Small Reactors from Highly-Enriched to Low-Enriched Uranium

The American Nuclear Society has been following the NRC activities concerning the HEU/LEU Conversion. We understand that the Commission is preparing to issue a ruling directing all licensed reactors which use HEU fuel elements to "convert promptly" to LEU. We believe there are several issues that should be recognized in framing such a ruling or directive:

1. Education is one of our highest national priorities because of its relevance to U.S. progress and security. Research/teaching reactors are of major importance in assuring an adequate supply of professionally trained workers for the essential fields of nuclear engineering, nuclear physics, nuclear chemistry and activation analysis.

2. Licensed teaching/research reactors are an important source of short-lived isotopes for medical research and diagnosis. Reactor shutdowns would probably lead to the cancellation of many of these programs.

3. While conversion feasibility was demonstrated at Argonne for some reactors, detailed technology for others is still undemonstrated. Further, reload to constant power but reduced flux can significantly affect important programs in radioisotope production and activation analyses.

4. The concept that a HEU/LEU conversion in the U.S. is a good role model for the rest of the world seems to ignore two factors:

    a. Converting the licensed university reactors probably results in converting less than 15% of the U.S. HEU reactors.

b. The offshore concern has been the temptation for a non-weapons government to proceed with weapons technology and then suddenly divert the HEU. It would hardly seem that such a concern exists in the U.S.

5. Since such a directive or ruling seems to be motivated largely by considerations of foreign policy and not by concerns for public safety (in the accident consequence sense), we believe it is appropriate that the U.S. government bear the full cost of any ordered replacements and/or modifications or resulting relicensing. The Honorable Messieurs Ottinger, Markey and Wolpe appear to recognize this in their letter to you of January 26, 1984. It is very important that the timing of the directive should be coordinated with the timing of the funding.

Because of the importance of this matter to both medical research and education and the very real risk that unintended consequences will occur as a result of such a directive, I urge that full consideration be given to the above factors before the directive is finalized.

Sincerely yours,

Milt Levenson

Milton Levenson

ML/pw

cc ANS Executive Committee
O. J. Du Temple
E. Ricci

University of Notre Dame
Notre Dame, Indiana 46556

MAY 25 1984

May 23, 1984

Dr. Joseph N. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Palladino:

This letter is being written to express my concerns, both as an individual and as Chairman of the Education Division of the American Nuclear Society. These concerns are shared by Dr. Paul Turinsky, Professor and Chairman of Nuclear Engineering at North Carolina State University, Chairman of the Nuclear Engineering Department Heads Organization, and by Mr. A. Francis DiMeglio, Rhode Island Nuclear Science Center, Chairman of the Research, Test, and Training Reactors Group, both of whom I consulted in preparing this letter.

Our concerns arise from the Commission's apparent departure from its own procedures in its haste to draft and issue a rule with regard to conversion of University Research Reactors from HEU to LEU fuels without fully considering the impact of the proposed rule or alternative actions which may more effectively meet the concerns which gave rise to the proposed rule. An even greater and more unsettling departure from its normal procedure is the prospect that the Committee will impose "voluntary" measures for increased security at non-power reactors without any opportunity for discussion of the costs and benefits associated with that action. Some of these impacts and alternatives will be discussed at the American Nuclear Society meeting in New Orleans June 4 and at a meeting of the ACRS Subcommittee on Safeguards on June 12.

Commission policy, as set forth in NUREG-0885, we believe, calls for a systematic evaluation of risks and benefits associated with a proposed generic rulemaking. The proposed rule, in our view, warrants a more systematic look at the impacts and social costs of the proposed action and a more careful evaluation of possible alternative actions.

The cost-benefit analysis contained in the Regulatory Analysis supporting the HEU/LEU rulemaking has been described by some NRC staff as inadequate. Some other points which were raised with only casual and unsubstantiated discussion in staff presentations are:

1. The probable loss of several U.S. research reactors due to an inability to fund the expense of extended litigation provoked by the conversion to LEU. The social impact of such a loss could involve a reduction in the number of training facilities and programs available in the United States with a concomitant reduction in the number of students in those

programs. (This at a time when NRC and INPO studies estimate a need for more than 5,000 trained people for replacement and upgrading of operating staffs in U.S. power reactors.) The resulting curtailment of both physical and medical research programs in the U.S. may accelerate the development of these capabilities offshore, a development which may not be in the national interest.

2. From a risk assessment point of view, a prudent national policy to limit the flow of highly enriched material would devote maximum effort and resources to those situations where the amounts of material involved are largest and the levels of shipping and handling are high. A qualitative ranking of HEU uses and users suggests that low-power research reactors are at the bottom of such a list, with medium-power university reactors next lowest. A near-term changeover from HEU to LEU fuel in small research reactors may indeed "set a good example". It will not, however, reduce the diversion risks from the much larger inventories and material flows associated with larger, non-university reactors. These risks, it appears, will continue for several years (possibly four or five), regardless of the timing required of domestic university reactors. This consideration indicates a need to reevaluate the pace (in some cases, the need) for conversion to LEU. It is important that these conversion efforts not divert the staff and resources of DOE, NRC, and the State Department from the much larger non-domestic risks.

3. One of the apparent motives for NRC action in this area is the rise in terrorist activity and the postulation of highly coordinated, internationally supported, terrorists with substantial resources. Terrorists might have as objectives any combination of five items:
   a. personnel casualties;
   b. facilities damage;
   c. dispersion of radioactive material;
   a. diversion of HEU fuel; and
   e. symbolic activities aimed at raising and manipulating public alarm.

   We suggest that the proposed conversion to LEU fuel does not address or significantly impact items a through d, and appears to enhance the attractiveness of item e.

4. A systematic risk evaluation of potential diversion from small research reactors by a neutral, but well-informed, panel appears to us to be a necessary prelude to any rulemaking. A policy of reducing the tonnage flows of HEU in international commerce appears prudent, since the amounts of material in some single shipments and single locations appear

to be more than ample to make one or more nuclear explosive devices. The implication, however, that domestic research reactors present a comparable risk deserves a more careful evaluation. (Note that low power research reactors contain only a fraction of the amount of material required to make a plausible nuclear explosive.)

5. It may be that the Commission has substantiated information on risk exposures which are not known to universities, and which provide a sufficiently compelling basis for the "as soon as technically practical" guideline provided to the staff for conversion to LEU fuel. If such compelling evidence exists (particularly since conversion does not actually address most of the risks), we believe it proper that the Commission and/or appropriate security agencies share this information with affected members of the university community (on a classified basis if necessary). If such compelling evidence does not exist, we reiterate our belief that it is appropriate for the Commission and its staff to more carefully investigate the alternative actions and impacts noted above.

6. The $15 million expense, presumably to be funded by DOE, for HEU/LEU conversion envisioned in NUREG/CR-3666 will have no discernable educational benefit. The same amount used to upgrade obsolescent university laboratories would have a major impact on the quality of engineering education in this country. Absent the compelling evidence mentioned in (5) above, the Commission should not only consider whether the proposed measures are possible, but also whether they represent a reasonable use of scarce federal and university funds.

We request that at its meeting May 31, 1984 the Commission not take action to have the proposed HEU/LEU rule published for public comment, but rather follow its normal procedure of waiting for the report of the ACRS on the proposed rule before taking further action. Further, we request that the Commission follow its normal rulemaking procedure and not impose "voluntary" security requirements on university reactors in lieu of a more deliberate rulemaking procedure.

Sincerely,

John W. Lucey
Chairman
cation Division, ANS

cc: ACRS Subcommittee on Safeguar
A.F. DiMeglio
P. Turinsky

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone: (312) 352-6611 • Telecopier: (312) 352-0499 • Telex: 254635

PRESIDENT
Joseph M. Hendrie
Brookhaven National Laboratory
Building 197 - C
Upton, NY 11973 USA

June 11, 1984

The Hon. Nunzio J. Palladino
Chairman, United States Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Chairman Palladino:

Conversion of Fuel Elements of Non-Power Reactors from Highly-Enriched to Low-Enriched Uranium

As you may know, the American Nuclear Society sponsored a special session at its recent New Orleans meeting concerning the conversion of non-power reactors from the use of high enriched uranium fuel to low enriched uranium fuel. This session generated considerable discussion and concern because of the present approach by the NRC which effectively mandates conversion of all the non-power reactors to low enriched uranium. We believe that this conversion will most certainly result in the shut down of several of the operating reactors.

During the discussion, considerable pertinent evidence, not covered in past analyses, was presented concerning the relative diversion risks of various types of facilities which utilize high enriched uranium. From this evidence, it is clear that the risks of diversion from these non-power reactors is minimal. Based on this information (presented in the attached paper) we feel that a more systematic and thorough analysis of these risks would be prudent before issuance of a proposed rule.

The American Nuclear Society (ANS) offers its technical resources to assist the Commission in any way possible.

Sincerely,

Joe

Joseph M. Hendrie

JMH:eh
encls.

EPRI

RELATIVE DIVERSION EXPOSURES OF HIGH ENRICHMENT URANIUM: RELATION TO UNIVERSITY RESEARCH REACTORS

Edwin L. Zebroski
Energy Study Center
Electric Power Research Institute
Palo Alto, California

AMERICAN NUCLEAR SOCIETY

Special Session
on the
Use of Low Enrichment Fuel in Research Reactors
New Orleans, Louisiana
June 4, 1984

RELATIVE DIVERSION EXPOSURES OF HIGH ENRICHMENT URANIUM: RELATION TO UNIVERSITY RESEARCH REACTORS

Edwin L. Zebroski

Summary and Conclusions

The future conversion of overseas reactors with U.S.-supplied fuel to Low Enrichment Uranium (LEU) can be useful to reduce the possibility of diversion of significant amounts of strategic material. Future conversion, however, does not materially affect the existing residual risks associated with nearly 20 tons of High Enrichment Uranium (HEU) already exported. The characteristics of U.S. university research reactors appear to be in the lowest level of four categories of diversion risks. Five types of potential security questions are identified, including possible diversion or theft of material, although the quantities involved are insufficient to make nuclear explosives. Conversion of university reactors to low enrichment does not address four of the five issues.

The administrative processes involved in conversion to LEU as soon as technically practical appear nearly certain to lead to decommissioning some research reactors, with adverse impacts on U.S. capabilities for training, education, and research.

Simple administrative changes involving better communications appear likely to have a larger and much more timely effect in reducing residual risks involving public and local safety than all or most of the measures so far discussed, including conversion.

More thorough and systematic evaluation of the options which affect security appears prudent. The relative risks, benefits, and social impacts of changes in small domestic research reactors also would benefit from thorough study. Such thorough evaluations, beyond those so far evident, also appear to be consistent with policy statements published by the Nuclear Regulatory Commission for its own activities.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

June 18, 1984

Honorable Nunzio J. Palladino
Chairman
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Palladino:

SUBJECT: ACRS REPORT ON PROPOSED RULE FOR LIMITING THE USE OF HIGHLY ENRICHED URANIUM IN DOMESTIC RESEARCH AND TEST REACTORS

During its 290th meeting, June 14-16, 1984, the Advisory Committee on Reactor Safeguards reviewed a proposed rule for limiting the use of highly enriched uranium in research and test reactors and a plan to increase security measures at nonpower reactors that use high-enrichment fuel. These matters were considered also during a Subcommittee meeting in Washington, D.C. on June 12, 1984. During our review, we had the benefit of discussions with representatives of the NRC Staff, affected users, and advocates of reduced availability of highly enriched uranium fuel. We also had the benefit of the documents referenced.

With regard to the proposed rule limiting the use of highly enriched uranium in domestic research and test reactors (contained in SECY-84-211), we believe it would be more appropriate to base the proposal on national policy as articulated in the Nuclear Nonproliferation Policy Act of 1978 than to try to tie it to an unidentified threat. If the proposal is based on national policy, it would be appropriate for the government to pay the costs of conversion from high-enrichment (HEU) to low-enrichment uranium fuel (LEU), including such costs as the licensees may incur to accomplish the conversion. The conversion should be made in a gradual and orderly manner as funds and fuels become available. The rule should provide the licensees with the option of conversion to LEU or retaining HEU and meeting appropriate security requirements.

If, as a consequence of changes needed to effect a conversion, a license amendment is required, then a hearing with the opportunity for public intervention is possible. Before the Commission adopts a rule which might permit unrestricted intervention, we recommend that the Commission obtain an evaluation of the course, nature, costs, and other relevant aspects of previous contested hearings involving nonpower reactors to determine if the hearings are serving their intended function effectively. It may be that the rules regarding hearings involving low power research reactors should be different than those for power reactors.

The exceptions in the proposed rule which would permit special purpose reactors to continue to use highly enriched uranium fuel are appropriate and should be retained.

With regard to the plan and schedule to increase security measures at nonpower reactors that use highly enriched uranium fuel, we find no objections to the proposals. We see no need to proceed on an expedited schedule.

Two of the Committee members who participated in this review are associated with affected institutions listed in the draft public announcement of this rule. Because they are rendering advice of a general nature from which their employers will gain no preference over others, they are not required to refrain from participating in this matter. Dr. M. W. Carbon did not participate in this review.

Sincerely,

Jesse C. Ebersole

Jesse C. Ebersole
Chairman

References:

1. Rulemaking Issue (SECY-84-211) from William J. Dircks to the Commissioners, Subject: Proposed Rule for Limiting the Use of High-Enriched Uranium in Research and Test Reactors, dated May 22, 1984
2. Rulemaking Issue (SECY-84-216) from William J. Dircks to the Commissioners, Subject: Security Measures at Nonpower Reactors, dated May 25, 1984
3. Policy Issue (SECY-84-220) from William J. Dircks for the Commissioners, Subject: Research Reactor Fuel Conversion Developments and Related Issues, dated May 30, 1984
4. Report to NRC Commissioners, "Weapons-Grade Uranium on Campus - The Need to Convert Research Reactors to Lower Enrichment Fuels," by Daniel Hirsch, Stevenson Programs on Nuclear Policy, University of California, Santa Cruz, dated January 27, 1984
5. Letter from Donald E. Feltz, Nuclear Science Center, Texas A&M University System, to John C. McKinley, Advisory Committee on Reactor Safeguards, dated June 12, 1984, Subject: ACRS meeting of June 12, 1984 regarding proposed rule on HEU
6. Letter from James J. McGovern, Business Manager, Radiochemicals, Union Carbide Corporation to U. S. Nuclear Regulatory Commission, Subject: Issue of HEU to LEU conversion of research reactor fuel, dated June 12, 1984
7. Report by Edwin L. Zebroski, Energy Study Center, Electric Power Research Institute, "Relative Diversion Exposures of High Enrichment Uranium: Relation to University Research Reactors," dated June 4, 1984
8. Statement of William R. Mowry, License Administrator, GA Technologies, Inc. before the ACRS Subcommittee on Safeguards and Security dated June 12, 1984
9. Statement of Dr. David W. Hafemeister Before the NRC Regarding the Need to Convert Domestic Research Reactors from Highly Enriched to Low-Enriched Uranium Fuels, dated June 12, 1984
10. Statement of Paul L. Leventhal, Nuclear Control Institute, Before the Subcommittee on Safeguards and Security, ACRS, Regarding the Need to Convert Domestic Research Reactors From Highly Enriched to Low-Enriched Uranium Fuels, dated June 12, 1984

Mr. YOUNG. Thank you, Mr. DiMeglio.

Dr. Turinsky, I'll be right back. It will just be about 8 or 10 minutes, I think.

[Recess.]

Mr. YOUNG. Dr. Paul Turinsky, the chairman of the Nuclear Engineering Department Organization, Department of Nuclear Engineering, North Carolina State University. I guess it goes without saying, Doctor, that the University of Missouri's extremely interested in this particular aspect, so, like all the other witnesses, your full statement will be made a part of the record and you can summarize, sir, in the manner you'd like.

STATEMENT OF DR. PAUL J. TURINSKY, HEAD, DEPARTMENT OF NUCLEAR ENGINEERING, NORTH CAROLINA STATE UNIVERSITY, AND PAST CHAIRMAN, NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION

Dr. TURINSKY. Thank you for this opportunity to appear before you.

I am here in my capacity as the past chairman of the Nuclear Engineering Department Heads Organization, whose membership is composed of most of the department heads and chairmen of university nuclear engineering programs.

I will attempt to present the Nuclear Engineering Department Heads Organization's viewpoint on the impact of the NRC-proposed rule for required domestic research and test reactors to convert from high- to low-enriched uranium fuel. A number of the affected reactors are located at universities with nuclear engineering programs.

Other speakers before these subcommittees have discussed the need for this rule; therefore, I will mainly discuss the educational, research, and service costs associated with this rule. Nuclear engineering programs, other academic programs, government and industry utilize research and test reactors located at universities in a variety of fashions for the benefit of society.

Reactor laboratories are an important part of the nuclear engineering student's education. Through experiments students develop experimental and operational skills and reinforce reactor theory learned in the classroom.

In addition to reactor experiments, nuclear engineering students and students from other disciplines utilize the neutrons produced by reactors in a number of different teaching laboratories.

At North Carolina State University, chemistry, public health, geosciences, mechanical engineering, and nuclear engineering students all have regularly scheduled teaching laboratories which utilize our reactor.

Through the Department of Energy-sponsored Reactor-Sharing Program, campus reactors have been made available to high school, junior college, and university students for teaching laboratories and demonstrations. In addition to teaching, a wide variety of research is conducted on the higher power campus reactors. The focus of this research has shifted over the years from reactor physics to utilization of the neutrons produced by the reactor.

I believe the shift in focus has resulted in a decrease in the awareness of the amount of research conducted on campus reactors. Today, research reactors are used to produce short-lived radioisotopes which are used in medical research. Via prompt gamma analysis and neutron activation analysis, we are able to detect minute quantities of chemicals in samples. This capability is utilized in many research areas, including environmental research and geosciences research.

Neutron radiography allows us to look inside solid materials much like an x ray, but for different materials. The interaction of neutrons with condensed matter permits us to explore the molecular structure of liquids and solids. On a more applied level, neutron irradiation of a material enables us to assess the changes in the physical properties of this material with irradiation.

At several campus research reactors, materials used in power reactors, such as pressure vessel steels, are being irradiated in support of materials research. More refined techniques now allow us to determine the surface composition of certain materials, which has research applications in microelectronics and other areas.

I could continue with this list, but by now I trust you realize that campus reactors enhance research in a number of areas not normally associated with reactors and nuclear engineering.

In addition to education and research, campus reactors are utilized to deliver services. Most of the research topics previously mentioned also have a service component. For example, short-lived radioisotopes are used routinely in medical diagnostics and treatment. Neutron activation analysis is being used by the mining industry to assess the composition of ore deposits and by the Environmental Protection Agency to monitor pollution.

University reactors are also used in the training of the reactor operators of commercial nuclear powerplants owned by electric utilities.

The relevant question is how will the NRC-proposed rule to require domestic research and test reactors to convert from high- to low-fuel enrichment impact the educational, research and service benefits derived from such reactors? For certain reactors, a reduction in neutron intensity will occur as a result of the conversion. This would adversely affect certain research projects and reactor efficiency.

The proposed rule allows arguments to be presented to obtain an exemption from conversion under such circumstances, but the basis on which to decide whether such an exemption will be granted is unclear. The primary concern, however, is the closing down of a number of research and test reactors due to this rule and the resulting loss of all benefits associated with these closed reactors.

Other speakers before these subcommittees have addressed the financial and licensing concerns associated with the proposed rule, so I shall not dwell on these concerns.

Clearly, without substantial financial assistance provided by the Government to cover all conversion costs, including legal fees associated with potentially protracted licensing hearings, most campus reactors would shut down.

The Government, through the Department of Energy's University Reactor Fuel Assistance Program, has a history of providing such support and we would hope that they would honor their commitment to provide substantial financial and technical assistance if the proposed rule were to be adopted.

Our major concern is that even with substantial financial support from the Government, a number of university reactors will shut down, rather than convert. University administrators are beginning to view campus reactors as points of aggravation they can do without.

For universities with nuclear engineering programs, their reactors are many times tighly associated with these programs. Nuclear engineering programs, on average, are now much weaker today than they were several years ago. Bachelors and masters nuclear engineering enrollments are down 26 percent from past years. As a percentage of bachelors and masters total engineering enrollment, nuclear engineering enrollment has declined from 2.4 percent to 1.0 percent.

The percentage of foreign students in nuclear engineering doctorate programs has increased from 30 percent to 52 percent over the past 5 years. A Department of Energy manpower alert has been issued pointing out the low number of nuclear engineering PhD. degrees awarded to U.S. citizens. All of this deterioration has occurred in spite of an extremely healthy employment picture for nuclear engineering graduates.

These enrollment declines have produced lower student-to-faculty ratios in nuclear engineering programs during a time period when this ratio for other engineering programs has been greatly increasing. This fact, and the additional cost of operating a campus reactor, have made the cost of educating a nuclear engineering student several times greater than other engineering students.

Inadequate Federal support for nuclear engineering education and graduate research, as indicated by less than one-half of 1 percent of the Department of Energy's Office of Nuclear Energy's research budget going to support university has also weakened nuclear engineering graduate programs and resulted in underutilization of faculty research expertise.

Given this background of declining student enrollment, high university costs per student and inadequate Government support of graduate education for nuclear engineering programs, a number of programs have already closed or been merged with larger engineering programs. The current fragile nature of nuclear engineering programs increases the likelihood that university administrators will shut down campus reactors if the NRC-proposed rule on conversion was enacted, independent of Government financial support.

One need only examine the reasons why the University of California, Los Angeles, shut down their reactor to support this conclusion.

The Nuclear Engineering Department Heads Organization urges the Congress to object to the proposed conversion rule and to redirect the technical and financial resources of the Federal Government to address the current problems university nuclear engineering programs are experiencing. If these university problems are not shortly addressed, the United States will further default their leadership role in nuclear education and research to Europe and Japan.

The Committee on Science and Technology is to commend—is to be commended for reporting out H.R. 5244, which contains funding for nuclear fission research and development at universities to begin to address these problems.

I'd be happy to answer any questions now.

[The prepared statement of Dr. Turinsky follows:]

Testimony of Dr. Paul J. Turinsky
On Behalf Of The
Nuclear Engineering Department Heads Organization
on the NRC Proposed HEU to LEU Fuel Conversion Rule

September 25, 1984

Thank you for this opportunity to appear before the Subcommittees on Energy Development and Applications and Energy Research and Production. I am Dr. Paul J. Turinsky, Head of the Department of Nuclear Engineering at North Carolina State University. I am here in my capacity as past chairman of the Nuclear Engineering Department Heads Organization, whose membership is composed of most of the department heads and chairmen of university nuclear engineering programs. I will attempt to present the Nuclear Engineering Department Heads Organization's viewpoint on the impact of the Nuclear Regulatory Commission's proposed rule to require domestic research and test reactors to convert from high (HEU) to low (LEU) enriched uranium fuel. A number of the affected reactors are located at universities with nuclear engineering programs. Other speakers before these subcommittees will discuss the need for this NRC rule. Therefore, I will mainly discuss the educational, research and service costs associated with this rule.

Nuclear engineering programs, other academic programs, government and industry utilize research and test reactors located at universities in a variety of fashions for the benefit of society. Reactor laboratories are an important part of a nuclear engineering student's education. Through experiments the student develops experimental and operational skills, and reinforces the reactor theory learned in the classroom. In addition to reactor experiments, nuclear engineering students and students from other disciplines utilize the neutrons produced by reactors in a number of different teaching laboratories. At NCSU, chemistry, public health, geosciences, mechanical engineering and nuclear engineering students all have teaching laboratories which utilize our reactor. Through the DOE-sponsored Reactor Sharing Program, campus reactors have been made available to high school, junior college, and university students for teaching laboratories and demonstrations.

In addition to teaching, a wide variety of research is conducted on the higher power campus reactors. The focus of this research has shifted over the years from reactor physics to utilization of the neutrons produced by the reactor. I believe this shift in focus has resulted in a decrease in the awareness of the amount of research conducted on campus reactors. Today research reactors are used to produce short-lived radioisotopes which are used in medical research. Via prompt gamma analysis and neutron activation analysis we are able to detect minute quantities of chemicals in samples. This capability is utilized in many research areas, including environmental research and geosciences research. Neutron radiography allows us to look inside solid materials much like an X-ray, but for different materials. The interaction of neutrons with condensed matter permits us to explore the molecular structure of liquids and solids. On a more applied level, neutron irradiation of a material enables us to assess the changes in the physical properties of this material with irradiation. At several campus research reactors materials used in power reactors, such as pressure vessel steels, are being irradiated in support of materials research. More refined techniques now allow us to determine the surface composition of certain materials, which has research applications in microelectronics and other areas. I could continue with this list, but by now I trust you realize that campus reactors enhance research in a number of areas not normally associated with reactors and nuclear engineering.

In addition to education and research, campus reactors are utilized to deliver services. Most of the research topics previously mentioned also have a service component. For example, short-lived radioisotopes are used routinely in medical diagnostics and treatment. Neutron activation analysis is being used by the mining industry to assess the composition of ore deposits and by the Environmental Protection Agency to monitor pollution. University reactors are also used in the training of the reactor operators of commercial nuclear power plants owned by electric utilities.

The relevant question is how will the Nuclear Regulatory Commission's proposed rule to require domestic research and test reactors to convert from HEU to LEU fuel impact the educational, research and service benefits derived from such reactors. For certain reactors a reduction in neutron intensity will occur as a result of conversion. This would adversely affect certain research projects and reactor efficiency. The proposed rule allows arguments to be presented to obtain an exemption from conversion under such circumstances. The primary concern, however, is the closing down of a number of research and test reactors due to this rule and the resulting loss of all benefits associated with these closed reactors.

Other speakers before these subcommittees have addressed the financial and licensing concerns associated with the proposed rule, so I shall not dwell on these concerns. Clearly, without substantial financial assistance provided by the government to cover all conversion costs, including legal fees associated with potentially protracted licensing hearings, most campus reactors would shut down. The government, through the Department of Energy's University Reactor Fuel Assistance Program, has a history of providing such support, and we would hope that they would honor their commitment to provide substantial financial and technical assistance if the proposed rule were to be adopted.

Our major concern is that even with substantial financial support from the government, a number of university reactors will shut down rather than convert. University administrators are beginning to view campus reactors as points of aggravation they can do without. For universities with nuclear engineering programs, their reactors are many times tightly associated with these programs.

Nuclear engineering programs on average are now much weaker today than they were several years ago. BS plus MS nuclear engineering enrollments are down 26% from past years. As a percentage of BS plus MS total engineering enrollment, nuclear engineering enrollment has declined from 2.4% to 1.0%. The percentage of foreign students in Ph.D. programs has increased from 30% to 52% over the past five years. A Department of Energy Manpower Alert has been issued pointing out the low number of nuclear engineering Ph.D. degrees awarded to U.S. citizens. All of this deterioration has occurred in spite of an extremely healthy employment picture for nuclear engineering graduates. These enrollment declines have produced lower student to faculty ratios in nuclear engineering programs during a time period when this ratio for other engineering programs has been greatly increasing. This fact and the additional cost of operating a campus reactor have made the cost of educating a nuclear engineer several times greater than other engineering students. Inadequate federal support for nuclear engineering education and graduate research, as indicated by less than one half of one percent of DOE's Office of Nuclear Energy's research budget going to support universities, has also weakened nuclear engineering graduate programs and resulted in underutilization of faculty research expertise. Given this background of declining student enrollments, high university cost per student, and inadequate government support of graduate education for nuclear engineering programs, a number of programs have already folded or been merged with larger engineering programs. The current fragile nature of nuclear engineering programs increases the likelihood that university administrators will shut down campus reactors if the Nuclear Regulatory commission-proposed rule on HEU to LEU fuel conversion was enacted, independent of government financial support. One need only examine the reasons why the University of California at Los Angeles shut down their reactor to support this conclusion.

The Nuclear Engineering Department Heads Organization urges the Congress to object to the proposed HEU to LEU conversion rule and to redirect the technical and financial resources of the federal government to address the current problems university nuclear engineering programs are experiencing. The Committee on Science and Technology is to be commended for reporting out HR5244 which contains funding to begin to address these problems. This concludes my prepared testimony and I now welcome your questions.

The following publications provide more information relevant to the testimony of Dr. Turinsky.

Use of Research and Test Reactors

Proceedings of the International Symposium on the Use and Development of Low and Medium Flux Research Reactors, Kerntechnik, 44 (1984).

Nuclear Engineering Manpower Supply and Demand

Personnel Requirements, Education, and Training for Civilian Nuclear Activities, U.S. Department of Energy (1984).

DOE's Office of Nuclear Energy Research Support of Universities

Letter from Mr. Shelby T. Brewer to the Honorable James T. Broyhill, June 7, 1984

Mr. YOUNG. Thank you very much, Dr. Turinsky.

The—what I had proposed to do, because of the amount of rollcalls that have kept the panels waiting all afternoon—I have a series of about three questions and maybe each one of you could address the questions down the line there and then Mr. Walker, then, would be available to ask any other questions of the panel. How would that be, Robert, is that——

Mr. WALKER. Fine.

Mr. YOUNG. The three questions: How many university reactors do you believe will shut down if ordered to convert without significant financial help; and the second that I would pose, suppose the NRC decides to order the conversion of at least some research and test reactors, how would each one of you recommend that this proceed in the least painful manner; and then the third part of it, what actions would each of you recommend that this committee should take with regard to this matter?

Anybody want to try to—and I'll be happy to repeat the questions if——

Dr. TURINSKY. Let me try——

Mr. YOUNG. Fine, Doctor.

Dr. TURINSKY. Let me try the first one. If we don't get basically total support from the Department of Energy to complete these conversions, including the licensing support, the legal fees, the support of our personnel—prior Dr. Remick estimated 50 percent. My estimate would be double that basically, and that is I think we would lose the majority of the reactors we have unless the Department of Energy really provides total financial and technical support for this activity.

Even with that total support, I believe a number of reactors will shut down because of these other competing demands for resources on the campus. And basically they've been a thorn in the side of university administrators.

Mr. YOUNG. That seems to be the impression I got from talking to our university.

Anybody else care to react to that question that Dr. Turinsky had started—or any other portion of the three questions would be fine.

Dr. DIMEGLIO. I think I can only reinforce what Dr. Turinsky said about the number that would shut down. I think even with funding, there are at least four, and possibly six, reactors out of the 31 who have indicated that they would probably shut down rather than go this route.

Without having the possibility of litigation settled long before a proposed rule becomes a rule, I think the numbers—I think the numbers of reactors that would get themselves involved in litigation is extremely small, based on the UCLA experience.

Except for very, very high-powered reactors operated by the Government, I can only think of one—the National Bureau of Standards in this group of 31—I think a large number of them will simply disappear. They just would not get themselves involved in litigation.

The least painful way to proceed, if we must proceed, is a little bit like asking us to write our obituary, I think. I don't think there's a—I don't think there is a least painful way. I think that as far as the research reactor community is concerned that all of the—all of the ways that have been suggested—and there have not really been that many alternatives suggested, if you think about it—are all painful to some segment of the community.

Mr. YOUNG. Then, to add to the question, what about grants from the Department of Energy to some of the universities?

Dr. TURINSKY. Could I comment a little bit——

Mr. YOUNG. Yes.

Dr. TURINSKY [continuing]. On the least painful way to proceed? I've been involved in this issue now for almost a year coming up here and in the proposed rule, there is language about simplifying licensing, et cetera. All I need point to is what's happened to the power industry and the capability of NRC to simplify licensing in regard to power reactors and what happened at UCLA. It is beyond their current capabilities to simplify licensing. They may have every goodwill to do that, and the intention to do that, but the reality is they have not demonstrated any time in the past that they are capable of simplifying the licensing process.

Mr. YOUNG. Well, thank you. I'm pretty sure you have covered those three questions.

I wonder if Mr. Walker——

Mr. WALKER. Yeah, thank you, Mr. Chairman, just a couple of questions, and I'm sorry I'm late and maybe these were covered before, but is—is—are there any other countries in the world where their research facilities are being asked to make this kind of conversion?

Dr. DIMEGLIO. The national—one of the reasons for asking the domestic research reactors to make this conversion—these conversions—is to demonstrate to other countries the good faith of the United States. The original thrust of this program was overseas reactors, and for—perhaps this is one of the reasons why the domestic research reactor community only recently, within the last couple of years, began to realize the full impact on their operations of this proposal because in the early days, the proposal really did not apply to them very seriously.

Some of the earlier speakers have mentioned the efforts being made by the State Department and the Department of Energy to convince overseas reactors that they should be converting to low-enriched uranium.

Mr. WALKER. But the—but the potential is, unless those kinds of agreements were arrived at, that the research now being done would move offshore.

Dr. DIMEGLIO. I think a lot of the research that would have been traditionally done in our reactors already has moved offshore——

Mr. WALKER. But that would be particularly true if these reactors shut down.

Dr. DIMEGLIO. Oh, very definitely, right.

Mr. WALKER. The problem, as I understand it, is one of security, the question of whether or not somebody could accumulate enough highly enriched uranium to build a weapon, to build a bomb. How—how many—well, let me put it this way, how much material is at each of your sites that could be used for such a purpose?

Dr. DIMEGLIO. Yes, the Department of Energy, in the previous panel, estimated that for unirradiated fuel currently at nonpower reactors, there is about 28 kilograms. They are convinced that with rather simple techniques, they could get the amount at all the nonpower reactors down to 18 kilograms or less. This is simply by making DOE facilities available for storage of this fuel, which we then call upon as we need.

Incidentally, one of the questions——

Mr. WALKER. That's the total amount available at all——

Dr. DIMEGLIO. At all——

Mr. WALKER [continuing]. At all facilities.

Dr. DIMEGLIO. Right——

Mr. WALKER. Now——

Mr. DIMEGLIO [continuing]. At all of those facilities, right.

Mr. WALKER. In other words, someone, in order to accumulate enough material—and I don't know how that relates to the amount of—of material you would need for a weapon of any size, but you would have to accumulate an awful lot of material from an awful lot——

Dr. DIMEGLIO. Yes.

Mr. WALKER [continuing]. Of sites in order to——

Dr. DIMEGLIO. Dr. Zebroski mentioned earlier this afternoon that if you—if you decided to store all of this at DOE high-security facilities, then you would just about have to hit all the facilities, all the nonpower reactors, to accumulate enough fuel—enough high-enriched uranium to produce some sort of weapon——

Mr. WALKER. So that is a security safeguard that could be developed. In other words, we could develop security safeguards that——

Dr. DIMEGLIO. And, in fact, there has been an awful lot of voluntary work done in this area already. For example, on a personal note again, at Rhode Island, we used to keep 30 elements fresh sitting in our fuel safe. We've now reduced that to never having more than four because the Department of Energy provides a site which—from which we can draw on a few days' notice.

To answer your question, Mr. Young, from earlier, the cost of shipping new fuel to a facility—at least to the type of fuel we use—is not really a very large amount of money, to draw from the central repository.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. YOUNG. Well, thank you very much. If there are no other questions before the committee, I want to thank this panel and the previous panels for—for taking so long, but I don't think the continuing resolution had been planned at the same time that the hearing had been set.

So I want to thank you all on behalf of the chairman and the chairman of the full committee for your fine presentation this afternoon and the committee will now stand adjourned.

Thank you very much. Thank you, Bob.

Mr. WALKER. Sure, Bob, thank you.

[Whereupon, at 5:20 p.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

APPENDIX 1

QUESTIONS AND ANSWERS SUBMITTED FOR THE RECORD

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
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October 10, 1984

Hon. Nunzio J. Palladino
Chairman
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Palladino:

We thank the Commission and the ACRS for the excellent testimony presented by Commissioners Bernthal and Asselstine, and Messrs. Ebersole, Mark and Remick at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel. Their remarks will be helpful to the Subcommittees in formulating a position on this matter.

We would like to supplement the record of the hearing with their responses to the attached questions. We would appreciate receiving these responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

Don Fuqua
DON FUQUA, Chairman
Committee on Science
and Technology

Marilyn Lloyd
MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachments

Additional Questions for Commissioners Bernthal and Asselstine

1. Has the Department of State asked the NRC to promulgate a rule requiring conversion from HEU to LEU fuel? If not, why is NRC proposing to take action based, in large part, on foreign policy considerations?

   Please identify the domestic and foreign research reactors that (1) have converted to LEU fuel, (2) can now be converted to LEU fuel but haven't done so, and (3) cannot convert to LEU fuel because the technology has not been demonstrated.

2. Is either irradiated and unirradiated HEU fuel directly usable to make an explosive device, or is some kind of processing required to extract and concentrate the HEU?

3. Do you agree with Dr. Zebroski's remark that "to make a single basic nuclear explosive, it would take the in-core fuel inventory of at least three of the research reactors with largest inventories, and about nine of the reactors with the smallest inventories"?

4. Do you agree with Dr. Zebroski's comment that "reactors with lifetime cores, which nominally have much less than a kilogram [of HEU] on site, may be reasonably found to be exempt from [conversion]"?

5. Have you had any discussions with the DOE to seek their agreement to store fresh fuel for university research reactors?

   Is this option an alternative to converting some or all reactors to LEU fuel?

6. How many domestic research and test reactors have lifetime cores and why should these reactors also be required to convert to LEU?

7. Dr. Ebersole proposed a "gradual elimination" of HEU "on general principles." Would conversion to LEU as cores are replaced be an appropriate approach to this issue?

8. Do you agree with Dr. Turinsky's comment that most of the university reactors would shut down if all of the costs of conversion, including licensing support (legal fees) were not covered by the government?

9. Do you agree with Dr. DiMeglio's comment that "probably six" reactors would be closed down even with full funding by the government?

10. Would NRC support legislation to provide grants to universities to cover all costs of conversion, including licensing costs?

11. Will the NRC take into consideration the impact on nuclear engineering education in any promulgation of a rule requiring conversion to LEU fuel?

12. How does the close down issue affect the cost/benefit analysis associated with the regulations?

13. Could the NRC generically approve the conversion to LEU fuel and, if so, how would this generic approval minimize extended licensing proceedings?

14. Would the NRC support Mr. Remick's proposal that "Congress exempt the NRC from the requirement of a public hearing for this type of conversion"?

15. Dr. Bernthal, you indicated in your testimony a concern about terrorist acts. What kind of acts are you postulating?

    Is there a credible risk of such activity?

16. Has there ever been either a successful or unsuccessful attempt to divert HEU fuel from a domestic research and test reactor?

17. What is the impact on the cost of radiopharmaceuticals to the Nation's consumers if all research and test reactors are converted to LEU?

    Will prices go up, down or remain unchanged?

18. Are any additional security measures being considered as an appropriate alternative to reducing any identifiable threat of diversion or terrorist activity, and if so, what are their costs?

19. The most frequent of reported safeguards-related events involves bombs or bomb threats. How would conversion from HEU to LEU fuel decrease the frequency of such events?

20. How would conversion from HEU to LEU decrease the costs of safeguards to protect against bomb-related events?

21. The summary of the proposed rule states that "currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public." If this is indeed the case, then why is the rule being proposed?

22. The proposed rule states that "[a] matter of interest to the Commission in requiring conversion and establishing the schedule will be financial considerations." If the NRC considers these conversions to be so significant to the national interest, why is so much weight given to "financial considerations"?

23. The proposed rule defines LEU fuel as fuel in which the weight percent of uranium-235 is less than 20 percent. What is the practical lower limit of LEU fuel before one begins to get a significant increase in plutonium production?

24. What is your proposed schedule for implementing the proposed rule?

25. Dr. Bernthal, in your testimony, you noted that "one can never be certain that actions taken by us domestically will have the desired positive influence abroad." What assurances, if any, do you have that requiring these conversions will indeed encourage other nations to comply with U.S. nuclear nonproliferation goals?

26. Does the NRC have any independent expertise to assess the international impact of ordering a conversion of domestic research and test reactors to LEU fuel?

27. Are there foreign suppliers of research and test reactor HEU fuels, and if so, why wouldn't other nations buy such fuel from them rather than undertaking the expense of conversion?

28. Is the NRC prepared to provide funding to expedite any such conversions?

29. Can all domestic research and test reactors convert to LEU fuel and still accomplish all of their research, production or test goals? Has the NRC assessed the impact of any reduction of these goals, and if so, what are they?

30. If the NRC orders conversion of these reactors, has it been determined that any license amendments would be necessary?

31. What has the Department of State told you about their position on this issue?

32. What has DOE told you about the availability of LEU fuel for all domestic research and test reactors?

33. What was the impetus for the Commission's development of a rule requiring the conversion from HEU to LEU fuel?

34. Several witnesses at the hearing made references to the decision to close the U.C.L.A. reactor after the University had spent several years trying to relicense the reactor. Would you please comment on the U.C.L.A. litigation? What issues were raised?

CHAIRMAN

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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COMMITTEE ON SCIENCE
AND TECHNOLOGY

December 17, 1984

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
United States House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

We are pleased to respond to your letter of October 10, 1984 with responses to 28 of the 34 additional questions for the record of the hearing on Conversion of Research and Test Reactors to Low Enriched Uranium (LEU) fuel. We will provide the responses to the remaining six questions in the near future.

Since this hearing was conducted jointly by the Subcommittees on Energy Development and Applications and Energy Research and Production, we are also providing these responses to Chairman Lloyd.

Please contact us again whenever we can be of assistance.

Sincerely,

Nunzio Palladino

Nunzio J. Palladino

Enclosure:
As stated

QUESTION 2. IS EITHER IRRADIATED AND UNIRRADIATED HEU FUEL DIRECTLY USABLE TO MAKE AN EXPLOSIVE DEVICE, OR IS SOME KIND OF PROCESSING REQUIRED TO EXTRACT AND CONCENTRATE THE HEU?

ANSWER.

ACCORDING TO INFORMATION PROVIDED BY DOE WEAPONS EXPERTS, EITHER IRRADIATED OR UNIRRADIATED HEU USED IN NONPOWER REACTOR FUEL WOULD REQUIRE SOME KIND OF PROCESSING TO CONCENTRATE THE HEU IN ORDER TO FABRICATE A DEVICE OF REASONABLE SIZE AND WEIGHT. ALSO, THERE IS A CONSIDERABLE PERSONAL HAZARD TO AN ADVERSARY WHO TRIES TO USE IRRADIATED FUEL. UNDER CURRENT REGULATIONS, SOME SAFEGUARDS CREDIT IS GIVEN TO FUEL WITH AN EXTERNAL DOSE RATE ABOVE 100 REM/HOUR AT 3 FEET. HOWEVER, THE RADIATION DOES NOT PRECLUDE THE USE OF THAT FUEL.

QUESTION 3. DO YOU AGREE WITH DR. ZEBROSKI'S REMARK THAT "TO MAKE A SINGLE BASIC NUCLEAR EXPLOSIVE, IT WOULD TAKE THE IN-CORE FUEL INVENTORY OF AT LEAST THREE OF THE RESEARCH REACTORS WITH LARGEST INVENTORIES, AND ABOUT NINE OF THE REACTORS WITH THE SMALLEST INVENTORIES"?

ANSWER.

DR. ZEBROWSKI ONLY ADDRESSED FUEL IN-CORE; HOWEVER, SAFEGUARDS MUST BE CONCERNED WITH ALL CLASSES OF HEU FUEL ONSITE; I.E., FUEL IN-CORE, FRESH FUEL IN STORAGE, AND SPENT FUEL. WHEN ALL THREE CLASSES OF FUEL ARE CONSIDERED TOGETHER, SEVERAL OF THE RESEARCH REACTORS EACH HAVE MORE THAN THE FORMULA QUANTITY USED IN NRC REGULATIONS TO DENOTE A STRATEGICALLY SIGNFICANT QUANTITY OF MATERIAL.

QUESTION 5. (A) HAVE YOU HAD ANY DISCUSSIONS WITH THE DOE TO SEEK THEIR AGREEMENT TO STORE FRESH FUEL FOR UNIVERSITY RESEARCH REACTORS?

ANSWER.

WE HAVE HAD SOME INITIAL DISCUSSIONS WHICH ARE FAVORABLE; HOWEVER, NO FINAL AGREEMENTS HAVE BEEN MADE.

(B) IS THIS OPTION AN ALTERNATIVE TO CONVERTING SOME OR ALL REACTORS TO LEU FUEL?

ANSWER.

A REDUCTION IN THE AMOUNT OF FRESH HEU FUEL STORED ON SITE WILL DECREASE THE PROBABILITY OF MALEVOLENT USE OF THE MATERIAL. THIS ACTION, IF TAKEN ALONE, WOULD STILL LEAVE MOST LICENSEES WITH ONSITE HEU INVENTORIES OF SEVERAL KILOGRAMS IN THE REACTOR CORE AND IN STORAGE AS SPENT FUEL. FOLLOWING THE COMMENT PERIOD ON THE PROPOSED LEU FUEL CONVERSION RULE, SEVERAL VIABLE ALTERNATIVES MAY BE IDENTIFIED AND EVALUATED. ONE OF THESE ALTERNATIVES MAY WELL BE STRENGTHENED SECURITY, WHICH COULD BE COUPLED WITH MINIMIZATION OF FRESH FUEL INVENTORIES.

COMMISSIONER ASSELSTINE ADDS THAT WHILE THIS APPROACH MAY BE HELPFUL, IT IS NOT AN ALTERNATIVE TO CONVERSION TO LEU FUEL, WHERE CONVERSION IS PRACTICAL.

QUESTION 5. HOW MANY DOMESTIC RESEARCH AND TEST REACTORS HAVE LIFETIME CORES AND WHY SHOULD THESE REACTORS ALSO BE REQUIRED TO CONVERT TO LEU?

ANSWER.

OF THE APPROXIMATELY 31, NRC LICENSED, RESEARCH AND TEST REACTORS AUTHORIZED FOR USE OF HEU FUEL, TWENTY DO NOT REFUEL FREQUENTLY. THESE 20 HAVE BEEN DESIGNATED AS HAVING "LIFETIME CORES". A NUMBER OF DOE FACILITIES MAY BE SIMILARLY CLASSIFIED.

THESE "LIFETIME CORE" FACILITIES (ALMOST ALL POSSESS FROM 2 TO 5 KG. OF APPROXIMATELY 93% ENRICHED, LIGHTLY IRRADIATED HEU FUEL) HAVE BEEN INCLUDED WITHIN THE SCOPE OF THE PROPOSED RULE TO MINIMIZE THE RESIDUAL RISK OF MALEVOLENT USE OF HEU.

QUESTION 7. DR. EBERSOLE PROPOSED A "GRADUAL ELIMINATION" OF HEU "ON GENERAL PRINCIPLES". WOULD CONVERSION TO LEU AS CORES ARE REPLACED BE AN APPROPRIATE APPROACH TO THE ISSUE?

ANSWER.

THE ELIMINATION OF HEU FROM RESEARCH AND TEST REACTORS, AS DESCRIBED IN THE PROPOSED RULE, WOULD BE BASED ON A SCHEDULE WHICH TAKES INTO ACCOUNT MANY FACTORS: (1) DEVELOPMENT AND DEMONSTRATION OF APPROPRIATE LEU FUELS IN DOE'S RERTR PROGRAM, (2) THE GENERATION, THROUGH THE RERTR PROGRAM, OF THE DATA NECESSARY TO PERFORM REQUIRED SAFETY ANALYSES, (3) COMMERCIAL AVAILABILITY OF LEU FUEL ACCEPTABLE TO NRC FROM A SAFETY PERSPECTIVE, (4) THE EXTENT OF FINANCIAL AND OPERATIONAL SUPPORT PROVIDED BY THE FEDERAL GOVERNMENT THROUGH DOE, AND (5) SEVERAL OTHER FACTORS IMPORTANT TO CONVERSION IMPLEMENTATION. THEREFORE, THE CONVERSION PROCESS DESCRIBED IN THE PROPOSED RULE IS NOT A CRASH PROGRAM, BUT A SEVERAL YEAR PROGRAM DIRECTED AT MINIMIZING THE RESIDUAL RISK ASSOCIATED WITH POTENTIAL THEFT OR DIVERSION OF HEU FROM RESEARCH AND TEST REACTORS.

IF OUR RULE IS FINALIZED REQUIRING ONLY CONVERSION TO LEU FUEL AS CORES ARE REPLACED, THIS WOULD EXEMPT THE 20 "LIFETIME CORES", DESCRIBED IN THE ANSWER TO QUESTION 6, FROM THE

CONVERSION PROCESS. FOLLOWING THE COMMENT PERIOD ON THE PROPOSED RULE, REASONED EVALUATION AND CONSIDERATION OF THE COMMENTS ON A VARIETY OF SUGGESTED APPROACHES TO THIS ISSUE WILL BE MADE AND DOCUMENTED.

QUESTION 8. DO YOU AGREE WITH DR. TURINSKY'S COMMENTS THAT MOST OF THE UNIVERSITY REACTORS WOULD SHUT DOWN IF ALL OF THE COSTS OF CONVERSION, INCLUDING LICENSING SUPPORT (LEGAL FEES) WERE NOT COVERED BY THE GOVERNMENT?

ANSWER.

THE COMMISSION HAS RECEIVED MANY COMMENTS FROM THE UNIVERSITY RESEARCH REACTOR COMMUNITY ON CONVERSION. THE COMMENTS INDICATE THAT REDUCED ENROLLMENT IN NUCLEAR ENGINEERING PROGRAMS COUPLED WITH THE RELATIVELY HIGH COST OF OPERATING A CAMPUS REACTOR ARE LEADING UNIVERSITY ADMINISTRATORS TO CONSIDER FACILITY DECOMMISSIONINGS. IN THE PROPOSED RULE, THE COMMISSION HAS SOLICITED COMMENTS ON THE ECONOMIC CONSIDERATIONS OF THE PROPOSED CONVERSION WITH THE INTENT OF QUANTIFYING IN THE FAIREST MANNER, THE POTENTIAL FOR UNIVERSITY REACTOR SHUTDOWNS AS A RESULT OF ANY IMPOSED FINANCIAL BURDEN. IN AN ATTEMPT TO ADDRESS FINANCIAL CONCERNS, THE COMMISSION HAS SUPPORTED EFFORTS TO OBTAIN FEDERAL FUNDING THROUGH THE DEPARTMENT OF ENERGY TO COVER THE COST OF THE NEW LEU FUEL AND THE PROCESS OF CONVERTING NON-POWER REACTORS FOR ITS USE. IN ADDITION, WE WILL ATTEMPT TO APPLY A GENERIC LICENSING APPROACH TO CONVERSION IN ORDER TO MINIMIZE OR ELIMINATE LICENSEE ADMINISTRATIVE COSTS AND AVOID DISRUPTION OF ONGOING RESEARCH AND EDUCATION PROGRAMS.

Commissioner Asselstine believes that the continued use of HEU fuel in domestic research reactors is likely to lead to enhanced physical security measures, particularly if there is an actual attempt to steal or divert this material or to sabotage one of these facilities. He notes that, unlike most of the cost of conversion to LEU fuel, the cost of these enchanced physical security measures will be borne by the licensee rather than the Federal government. Further, Commissioner Asselstine suspects that a serious security incident at one of these facilities could well cause many academic institutions to reevaluate their research reactor programs. This could lead to the loss to the country of these valuable educational and research tools.

Commissioner Bernthal believes many university reactors would indeed be shut down if the costs of conversion, including licensing support, were not covered by the government. He also believes that it is quite possible some reactors would be closed, even given full funding by the Federal Government.

Commissioner Roberts would invite your attention to item 2 of his memo to the Commission (see attachment).

Chairman Palladino believes that all of the foregoing comments by Commissioners have merit and should be considered by the Commission in future actions associated with this rulemaking.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
COMMISSIONER

November 19, 1984

MEMORANDUM FOR: Chairman Palladino
Commissioners Asselstine
Commissioner Bernthal
Commissioner Zech

FROM: Thomas M. Roberts

SUBJECT: CONVERSION FROM HEU TO LEU IN NON-POWER REACTORS

On November 9, 1984 my special assistant, Maria Lopez-Otin, met with Mr. Frank DiMeglio, chairman of the National Organization of Test, Research and Training Reactors (TRTR). She found the exchange of views most valuable. I would like to bring to your attention some of the noteworthy points discussed at their meeting:

- Mr. DiMeglio indicated this was the first time that the idea of a possible trade-off between additional physical security and conversion to LEU to achieve a reduction of diversion risks to acceptable levels was discussed.

  In this regard, I believe the Commission should encourage DOE to allow Argonne to use its RERTR research funding to study alternatives to reduction of HEU. For example, Argonne could study the use of HEU with reduced inventories (longer life cores because of higher densities and appropriate security measures) or using additives to the HEU core to make separation more difficult (Triga core).

- Ms. Lopez-Otin and Mr. DiMeglio discussed the need for license amendments. Mr. DiMeglio stated that conversations and correspondence with potential intervenors indicated that although they fully support conversion, it is not clear to him that there would not be interventions in the conversion licensing proceedings. This suggests to me that the idea of licensing the conversion by generic rulemaking is still quite problematical. I believe NRC should investigate DOE's willingness to fund the conversion licensing including intervention.

- Mr. DiMeglio also indicated that the majority of the facilities meet and go beyond existing security regulations. He stated that if there are some facilities that are not performing up to par the NRC can count on the resources of the TRTR to assist in the settlement of that situation. I believe the Commission should encourage our staff to routinely meet with the TRTR group to discuss how best to pursue our mutual goals.

By copy of this memorandum, I am asking the staff about the merit and feasibility of the above points.

cc: EDO
NMSS
SECY
OPE

QUESTION 9. DO YOU AGREE WITH DR. DIMEGLIO'S COMMENT THAT "PROBABLY SIX" REACTORS WOULD BE CLOSED DOWN EVEN WITH FULL FUNDING BY THE GOVERNMENT?

ANSWER.

COMPLETELY UNRELATED TO THE ISSUE OF CONVERSION TO LEU FUEL, SEVERAL LICENSEES HAVE INDICATED AN INTENT TO DECOMMISSION THEIR FACILITIES. HOWEVER, THE COMMISSION HAS RECEIVED INDICATIONS THAT, IN SOME OF THESE CASES, THE POTENTIAL CONVERSION ACTION IS A FACTOR IN THEIR DECISION. AS INDICATED IN THE RESPONSE TO QUESTION 8, REDUCED ENROLLMENTS IN NUCLEAR ENGINEERING PROGRAMS COUPLED WITH A RELATIVELY HIGH COST OF OPERATING A CAMPUS REACTOR ARE ALSO MAJOR FACTORS INFLUENCING DECOMMISSIONING DECISIONS.

COMMISSIONER BERNTHAL BELIEVES MANY UNIVERSITY REACTORS WOULD INDEED BE SHUT DOWN IF THE COSTS OF CONVERSION, INCLUDING LICENSING SUPPORT, WERE NOT COVERED BY THE GOVERNMENT. HE ALSO BELIEVES THAT IT IS QUITE POSSIBLE SOME REACTORS WOULD BE CLOSED, EVEN GIVEN FULL FUNDING BY THE FEDERAL GOVERNMENT.

QUESTION 10. WOULD NRC SUPPORT LEGISLATION TO PROVIDE GRANTS TO UNIVERSITIES TO COVER ALL COSTS OF CONVERSION, INCLUDING LICENSING COSTS?

ANSWER.

THE NRC HOLDS THE VIEW THAT CONVERSION COSTS BORNE BY ALL LICENSEES SHOULD BE FINANCED BY THE FEDERAL GOVERNMENT. FURTHERMORE, WE WOULD STRONGLY SUPPORT THE APPROPRIATION OF THIS REQUIRED FUNDING TO DOE OR ANOTHER FEDERAL AGENCY OTHER THAN THE NRC. HISTORICALLY, DOE HAS PROVIDED SIGNIFICANT SUPPORT TO RESEARCH AND TEST REACTOR PROGRAMS AND HAS PROVIDED FUEL FOR THE UNIVERSITY REACTORS. THE NRC MIGHT SUPPORT LEGISLATION TO PROVIDE GRANTS TO UNIVERSITIES TO COVER COSTS OF CONVERSION FROM HEU TO LEU, INCLUDING LICENSING COSTS, IF DOE COULD NOT OBTAIN SUFFICIENT FUNDS TO ASSIST THE CONVERSION PROCESS AND IF THE LICENSEES COULD SHOW THAT THE LICENSING COSTS WOULD BE A SIGNIFICANT BURDEN FOR THEM TO SHOULDER. NRC BELIEVES THAT ITS FUNDING OF CONVERSIONS WOULD BE INCONSISTENT WITH ITS STATUTORY ROLE OF REGULATION OF THE NUCLEAR INDUSTRY.

COMMISSIONER ASSELSTINE IS NOT YET PERSUADED THAT THE FEDERAL GOVERNMENT SHOULD PAY FOR THE CONVERSION OF COMMERCIAL NON-POWER REACTORS TO LEU FUEL. COMMISSIONER ASSELSTINE WOULD SUPPORT LEGISLATION TO PROVIDE GRANTS TO UNIVERSITIES TO COVER CONVERSION COSTS, IF DOE COULD NOT OBTAIN SUFFICIENT FUNDS TO ASSIST THE UNIVERSITIES IN THE CONVERSION.

QUESTION 11. WILL THE NRC TAKE INTO CONSIDERATION THE IMPACT ON NUCLEAR ENGINEERING EDUCATION IN ANY PROMULGATION OF A RULE REQUIRING CONVERSION TO LEU FUEL?

ANSWER.

THE COMMISSION RECOGNIZED THAT PROMULGATION OF THE PROPOSED RULE COULD HAVE POTENTIAL IMPACTS ON NUCLEAR ENGINEERING EDUCATION. THE RULEMAKING PROCESS PRESENTS AN OPPORTUNITY FOR AFFECTED LICENSEES TO EXPLICITLY IDENTIFY THESE IMPACTS AND SEVERAL COMMENTORS HAVE SUBMITTED INFORMATION SPECIFICALLY ADDRESSING THE IMPACTS ON NUCLEAR ENGINEERING EDUCATION. THESE IMPACTS WILL BE EVALUATED AND CONSIDERED BY THE COMMISSION IN MAKING ITS DECISION REGARDING FINAL ACTION ON THE PROPOSED RULE.

- - -

QUESTION 12. HOW DOES THE CLOSE DOWN ISSUE AFFECT THE COST/BENEFIT ANALYSIS ASSOCIATED WITH THE REGULATIONS?

ANSWER.

THE REGULATORY (I.E., COST/BENEFIT) ANALYSIS SUPPORTING THE ISSUANCE OF THE PROPOSED RULE IDENTIFIED CLOSE DOWNS AS A POTENTIAL IMPACT OR COST ASSOCIATED WITH THE PROPOSED RULE. BASED ON AN EVALUATION OF THE COMMENTS AND OTHER INFORMATION, THE SPECIFIC IMPACTS OF POTENTIAL CLOSE DOWNS WILL BE DEFINED TO THE MAXIMUM POSSIBLE EXTENT. ALTHOUGH THESE IMPACTS MAY NOT BE READILY CONVERTIBLE INTO QUANTIFIABLE COSTS, THEY WILL BE PRESENTED IN A MANNER WHICH ALLOWS FOR THEIR FAIR APPRAISAL.

QUESTION 13. COULD THE NRC GENERICALLY APPROVE THE CONVERSION TO LEU FUEL AND, IF SO, HOW WOULD THIS GENERIC APPROVAL MINIMIZE EXTENDED LICENSING PROCEEDINGS?

ANSWER.

MANY OF THE LICENSED NON-POWER REACTORS ARE LOW POWER FACILITIES WHICH CAN BE GROUPED INTO SEVERAL DESIGN CATEGORIES. THEREFORE, THE NUMBER AND EXTENT OF THE SAFETY ANALYSES REQUIRED OF LICENSEES TO ACHIEVE CONVERSION COULD BE REDUCED SIGNIFICANTLY. FURTHERMORE, IF THE SAFETY REVIEWS INDICATE THAT THE SAFETY MARGINS ASSOCIATED WITH EXISTING TECHNICAL SPECIFICATIONS REMAIN ESSENTIALLY UNCHANGED AND THE CONVERSION DOES NOT INVOLVE AN UNREVIEWED SAFETY QUESTION AND NO OTHER LICENSE CHANGE IS REQUIRED, CONVERSION COULD BE ACHIEVED WITHOUT PRIOR NRC APPROVAL. IT IS EXPECTED THAT IN MOST CASES, HOWEVER, A LICENSE AMENDMENT WOULD BE REQUIRED AND THIS PROCESS ALLOWS THE POSSIBILITY OF PUBLIC INTERVENTION AND AN ADJUDICATORY HEARING. CODIFICATION, THROUGH A RULEMAKING PROCEEDING, OF THE SAFETY ENVELOPES WITHIN WHICH SAFETY APPROVALS WOULD BE GRANTED, WOULD PROVIDE FOR PUBLIC PARTICIPATION BUT NOT REQUIRE PUBLIC HEARINGS.

QUESTION 14. WOULD THE NRC SUPPORT MR. REMICK'S PROPOSAL THAT "CONGRESS EXEMPT THE NRC FROM THE REQUIREMENT OF A PUBLIC HEARING FOR THIS TYPE OF CONVERSION"?

ANSWER.

THE NRC BELIEVES THAT LEGISLATION AS SUGGESTED BY MR. REMICK IS UNNECESSARY IF THE FUEL CONVERSION AND LICENSE AMENDMENT PROCESS CAN BE CONDUCTED AS INDICATED IN THE ANSWER TO QUESTION 13 AND BELOW.

THE NOTICE OF PROPOSED RULEMAKING, AND COMMISSIONER BERNTHAL IN HIS TESTIMONY, SUGGESTED USE OF A GENERIC LICENSING APPROACH TO CONVERSION WHICH COULD MINIMIZE OR ELIMINATE LICENSEE ADMINISTRATIVE COSTS AND AVOID DISRUPTION OF ONGOING RESEARCH AND EDUCATION PROGRAMS. THIS WOULD MEAN THE DEVELOPMENT OF GENERIC ENVELOPES OF SAFETY LIMITS AND LIMITING CONDITIONS FOR OPERATION FOR THE SEVERAL TYPES OF RESEARCH REACTORS, WHICH COULD BE CODIFIED THROUGH THE RULEMAKING PROCESS. THE RULE WOULD PERMIT THE OPERATION OF REACTORS FALLING WITHIN THE "ENVELOPES" DEFINED FOR LEU FUEL. THIS APPROACH WOULD ALLOW THE RULE TO BE INVOKED TO EFFECTUATE

CONVERSION. SUCH AN APPROACH WOULD NOT ELIMINATE PUBLIC PARTICIPATION IN THE CONVERSION ALTOGETHER, SINCE A MEMBER OF THE PUBLIC COULD COMMENT ON THE PROPOSED RULE OR REQUEST A HEARING IN A RULEMAKING PROCEEDING. HOWEVER, AS THE NRC HAS INTERPRETED THE ATOMIC ENERGY ACT AND THE ADMINISTRATIVE PROCEDURE ACT, A HEARING WOULD NOT BE REQUIRED IN THOSE CIRCUMSTANCES.

QUESTION 15. (A) DR. BERNTHAL, YOU INDICATED IN YOUR TESTIMONY A CONCERN ABOUT TERRORIST ACTS. WHAT KIND OF ACTS ARE YOU POSTULATING?

ANSWER.

THE NRC IS NOT POSTULATING SPECIFIC TERRORIST ACTS. OUR PRESENT SECURITY REQUIREMENTS FOR MODERATELY SIGNIFICANT QUANTITIES OF HEU ARE BASED ON THE PREMISE THAT IT WOULD BE DIFFICULT FOR AN ADVERSARY TO CARRY OUT COORDINATED SIMULTANEOUS THEFTS TO ACCUMULATE A STRATEGICALLY SIGNIFICANT QUANTITY OF HEU WITHOUT PREMATURE DISCOVERY. HOWEVER, RECENT FOREIGN TERRORIST ACTS IN OTHER COUNTRIES HAVE REDUCD OUR CONFIDENCE ON EARLY DISCOVERY. INDEED, EXCESSIVE PUBLICITY ATTACHED TO THIS ISSUE MAY ITSELF HAVE INCREASED THE RISK OF SUCH ACTS, HOWEVER MISGUIDED AND UNLIKELY TO SUCCEED IN THEIR OBJECTIVES THEY MIGHT BE. EVEN AN UNSUCCESSFUL ATTEMPT COULD HAVE A PROFOUNDLY ADVERSE IMPACT ON ALL RESEARCH REACTORS.

(B) IS THERE A CREDIBLE RISK OF SUCH ACTIVITY?

ANSWER.

CURRENTLY AVAILABLE INFORMATION CONTAINS NO INDICATION OF A SPECIFIC THREAT AIMED AT A DOMESTIC NUCLEAR FACILITY. HOWEVER, RECENT COORDINATED ACTS BY INTERNATIONAL TERRORISTS HAVE SHOWN THAT THE ASSUMPTION THAT IT IS DIFFICULT TO CARRY OUT SIMULTANEOUS SUCCESSFUL THEFTS OF HEU WITHOUT PREMATURE DISCOVERY IS IN QUESTION. BECAUSE OF THIS, THE NRC BELIEVES IT IS PRUDENT TO CONSIDER ADDITIONAL SECURITY MEASURES TO RESTORE THE ORIGINAL LEVEL OF CONSERVATISM IN THE PHYSICAL PROTECTION REQUIREMENTS.

QUESTION 17. WHAT IS THE IMPACT ON THE COST OF RADIOPHARMACEUTICALS TO THE NATION'S CONSUMERS IF ALL RESEARCH AND TEST REACTORS ARE CONVERTED TO LEU? WILL PRICES GO UP, DOWN OR REMAIN UNCHANGED?

ANSWER.

RADIOPHARMACEUTICAL PRODUCTION IS CARRIED ON BY ONLY A SMALL NUMBER OF U.S. NON-POWER REACTORS. INFORMATION PRESENTED AT THE 1984 INTERNATIONAL MEETING ON THE RERTR PROGRAM INDICATES THAT CASE STUDIES MUST BE PERFORMED TO ESTABLISH IF A SPECIFIC CAPABILITY OF A NON-POWER REACTOR IS ENHANCED, REMAINS THE SAME, OR IS REDUCED THROUGH THE CONVERSION TO LEU OR REDUCED ENRICHMENT HEU FUEL. IF THE CAPABILITY OF A FACILITY TO COST-EFFECTIVELY PRODUCE RADIOPHARMACEUTICALS IS SIGNIFICANTLY IMPACTED, EXEMPTION FROM A CONVERSION REQUIREMENT CAN BE A CONSIDERATION UNDER THE UNIQUE PURPOSE PROVISIONS OF THE PROPOSED RULE.

INFORMATION FROM THE RERTR PROGRAM ALSO INDICATES THAT CASE STUDIES MUST BE PERFORMED TO ESTABLISH IF FUEL CYCLE COSTS ARE INCREASED, DECREASED, OR REMAIN THE SAME IF A FACILITY IS CONVERTED TO LEU OR REDUCED ENRICHMENT HEU FUEL. AGAIN, IF AN INCREASE IF FUEL CYCLE COST COULD BE DEMONSTRATED TO SIGNIFICANTLY IMPACT ON THE COST OF RADIOPHARMACEUTICALS, EXEMPTIONS FROM A CONVERSION REQUIREMENT COULD BE CONSIDERED UNDER THE UNIQUE PURPOSE PROVISIONS OF THE PROPOSED RULE.

THE COMMISSION VIEW IS THAT THE COSTS OF THE NECESSARY STUDIES FOR UNIVERSITY AND COMMERCIAL LICENSEES SHOULD LARGELY OR ENTIRELY BE FINANCED BY THE FEDERAL GOVERNMENT, (I.E., THROUGH THE RERTR PROGRAM.)

THE ABOVE CONSIDERATIONS, TOGETHER WITH THE STATED IMPLEMENTATION PROVISIONS OF THE PROPOSED RULE, SHOULD MINIMIZE OR ELIMINATE ANY IMPACTS ON THE COST OF RADIOPHARMACEUTICALS.

QUESTION 18. ARE ANY ADDITIONAL SECURITY MEASURES BEING CONSIDERED AS AN APPROPRIATE ALTERNATIVE TO REDUCING ANY IDENTIFIABLE THREAT OF DIVERSION OR TERRORIST ACTIVITY, AND IF SO, WHAT ARE THEIR COSTS?

ANSWER.

THE COMMISSION HAS CONSIDERED ADDITIONAL SECURITY MEASURES TO RESTORE THE LEVEL OF CONSERVATISM IN THE PROTECTION OF HEU AT RESEARCH AND TEST REACTORS. HOWEVER, TO DATE NO CONCLUSIONS HAVE BEEN REACHED REGARDING THE SCOPE OR NEED FOR THESE ADDITIONAL MEASURES. COST ESTIMATES FOR THESE ADDITIONAL MEASURES WILL BE DEVELOPED FROM INFORMATION GATHERED IN THE STANDARD PUBLIC COMMENT PROCESS FOR A PROPOSED RULE.

QUESTION 19. THE MOST FREQUENT OF REPORTED SAFEGUARDS-RELATED EVENTS INVOLVES BOMBS OR BOMB THREATS. HOW WOULD CONVERSION FROM HEU TO LEU FUEL DECREASE THE FREQUENCY OF SUCH EVENTS?

ANSWER.

THE MOST FREQUENTLY REPORTED SAFEGUARDS-RELATED EVENTS ARE BOMB THREATS, I.E., WHERE SOMEONE CLAIMS TO HAVE PLACED AN EXPLOSIVE SUCH AS DYNAMITE AT A FACILITY. THE VAST MAJORITY OF SUCH THREATS ARE DIRECTED AT POWER REACTORS AND ONLY A FEW PERCENT OF THESE INVOLVE RESEARCH AND TEST REACTORS. BECAUSE OF THE TYPICAL NATURE OF THESE THREATS, IT IS NOT EXPECTED THAT CONVERSION TO LEU WOULD CHANGE THEIR FREQUENCY.

QUESTION 20. HOW WOULD CONVERSION FROM HEU TO LEU DECREASE THE COST OF SAFEGUARDS TO PROTECT AGAINST BOMB-RELATED EVENTS?

ANSWER.

BECAUSE OF THE TYPICAL NATURE OF BOMB THREATS, IT IS NOT EXPECTED THAT CONVERSION TO LEU WOULD CHANGE THEIR FREQUENCY. THE LEVEL OF SAFEGUARDS REQUIRED AT A FACILITY VARIES WITH THE QUANTITY AND ENRICHMENT OF MATERIAL POSSESSED. THEREFORE, A TYPICAL CONVERSION FROM HEU TO LEU FUEL AT A RESEARCH REACTOR WOULD, UNDER CURRENT REGULATIONS, AUTOMATICALLY QUALIFY A LICENSEE FOR A LOWER LEVEL OF SAFEGUARDS REQUIREMENTS. POTENTIAL COST SAVINGS DUE TO THE CHANGES IN THE QUANTITY AND ENRICHMENT OF MATERIAL POSSESSED HAVE NOT BEEN QUANTIFIED BECAUSE THEY ARE HIGHLY SITE SPECIFIC.

QUESTION 21. THE SUMMARY OF THE PROPOSED RULE STATES THAT "CURRENTLY LICENSED NON-POWER REACTORS USING HEU FUEL ARE OPERATED WITHOUT UNDUE RISK TO THE HEALTH AND SAFETY OF THE PUBLIC." IF THIS IS INDEED THE CASE, THEN WHY IS THE RULE BEING PROPOSED?

ANSWER

UNDUE RISK DOES NOT MEAN ZERO RISK. THE RULE IS BEING PROPOSED TO IMPLEMENT THE NON-PROLIFERATION-RELATED ACTIONS CALLED FOR IN THE COMMISSION'S POLICY STATEMENT OF AUGUST 1982 AND TO FURTHER REDUCE THE RISK OF DOMESTIC THEFT OR DIVERSION OF HEU FUEL AND ITS MALEVOLENT USE. ELIMINATION OF TRAFFIC AND INVENTORIES OF HEU FUEL AT A FACILITY WOULD REDUCE THE THEFT OR DIVERSION RISK FROM THIS CLASS OF FUEL TO MINIMAL LEVELS.

QUESTION 22. THE PROPOSED RULE STATES THAT "[A] MATTER OF INTEREST TO THE COMMISSION IN REQUIRING CONVERSION AND ESTABLISHING THE SCHEDULE WILL BE FINANCIAL CONSIDERATIONS." IF THE NRC CONSIDERS THESE CONVERSIONS TO BE SO SIGNIFICANT TO THE NATIONAL INTEREST, WHY IS SO MUCH WEIGHT GIVEN TO "FINANCIAL CONSIDERATIONS"?

ANSWER.

THE COMMISSION SUPPORTS THE POLICY THAT REDUCING THE INTERNATIONAL TRAFFIC AND INVENTORIES OF HEU REDUCES THE RISKS OF PROLIFERATION THROUGH THEFT OR DIVERSION OF THIS MATERIAL. THE COMMISSION BELIEVES THAT THE FUEL DEVELOPMENT ACTIVITIES OF THE RERTR PROGRAM WERE UNDERTAKEN TO FURTHER A NATIONAL INTEREST. IN THE POLICY STATEMENT OF AUGUST 24, 1982, THE COMMISSION STATED THAT STEPS WOULD BE TAKEN TO ENCOURAGE THE ELIMINATION OF HEU INVENTORIES AT DOMESTIC REACTORS TO ENCOURAGE FOREIGN OPERATORS TO CONVERT IN THE INTEREST OF NON-PROLIFERATION OBJECTIVES. A SECOND REASON FOR CONVERSION IS BASED ON AN NRC POLICY TO REDUCE THE RESIDUAL RISK OF MALEVOLENT USE OF HEU DOMESTICALLY.

JUST AS THE RERTR PROGRAM REFLECTS THE "FINANCIAL CONSIDERATIONS" OF FOREIGN CONVERSIONS, THE COMMISSION BELIEVES THE DOMESTIC CONVERSIONS MUST BE ACHIEVED AT REASONABLE COST, MOST OF WHICH SHOULD BE BORNE BY THE GOVERNMENT.

QUESTION 24. WHAT IS YOUR PROPOSED SCHEDULE FOR IMPLEMENTING THE PROPOSED RULE?

ANSWER.

THE COMMENT PERIOD ON THE PROPOSED RULE ENDED ON NOVEMBER 2, 1984. WITHIN ABOUT 90 DAYS FROM THAT DATE, ALL COMMENTS ARE EXPECTED TO BE EVALUATED AND THE VALUE AND IMPACTS OF ANY VIABLE ALTERNATIVES WILL BE ASSESSED AND DOCUMENTED. THE COMMISSION WILL REVIEW THIS ASSESSMENT AND COULD DECIDE ON AN APPROPRIATE COURSE OF ACTION AS EARLY AS THE SPRING OF 1985.

QUESTION 25. DR. BERNTHAL, IN YOUR TESTIMONY, YOU NOTED THAT "ONE CAN NEVER BE CERTAIN THAT ACTIONS TAKEN BY US DOMESTICALLY WILL HAVE THE DESIRED POSITIVE INFLUENCE ABROAD." WHAT ASSURANCES, IF ANY, DO YOU HAVE THAT REQUIRING THESE CONVERSIONS WILL INDEED ENCOURAGE OTHER NATIONS TO COMPLY WITH U.S. NUCLEAR PROLIFERATION GOALS?

ANSWER.

THE U.S., TO OUR KNOWLEDGE, HAS NO EXPLICIT ASSURANCES THAT DOMESTIC CONVERSION WILL HAVE A POSITIVE INFLUENCE ABROAD. WE ARE AWARE, HOWEVER, THROUGH COMMENTS MADE TO THE NRC REPRESENTATIVES BY FOREIGN OFFICIALS AND FROM DISCUSSION WITH ARGONNE NATIONAL LABORATORY REPRESENTATIVES, THAT OTHER COUNTRIES ARE FOLLOWING CLOSELY OUR DOMESTIC ACTIONS TAKEN WITH REGARD TO REDUCING THE ENRICHMENT OF U.S. RESEARCH REACTORS, AND INDICATING THEIR EXPECTATIONS OF PARALLELISM IN U.S. AND FOREIGN CONVERSION EFFORTS. WE HOPE THAT U.S. EFFORTS TO CONVERT U.S. RESEARCH REACTORS DEMONSTRATE THE FACT THAT WE TAKE SERIOUSLY OUR DESIRE TO REDUCE UTILIZATION OF HEU AS A RESEARCH REACTOR FUEL. WE ALSO BELIEVE A POSITIVE DEMONSTRATION THAT DOMESTIC FACILITIES CAN BE CONVERTED TO THE USE OF LEU, PARTICULARLY IF THIS CAN BE ACCOMPLISHED ECONOMICALLY AND WITH MINIMUM ADVERSE IMPACT ON REACTOR OPERATIONS, CAN HAVE A POSITIVE INFLUENCE IN ENCOURAGING FOREIGN REACTOR OPERATORS TO USE LOWER ENRICHED FUELS AT AN EARLY DATE.

QUESTION 26. DOES THE NRC HAVE ANY INDEPENDENT EXPERTISE TO ASSESS THE INTERNATIONAL IMPACT OF ORDERING A CONVERSION OF DOMESTIC RESEARCH AND TEST REACTORS TO LEU FUEL?

ANSWER.

WHILE THE COMMISSION STAFF IS KNOWLEDGEABLE ON A NUMBER OF INTERNATIONAL MATTERS, INCLUDING THE CONVERSION SITUATION AND ATTITUDES ABROAD, WE DO NOT HAVE SPECIFIC STAFF EXPERTISE IN THIS PARTICULAR AREA. ACCORDINGLY, THE COMMISSION HAS CONSULTED CLOSELY WITH THE APPROPRIATE EXECUTIVE BRANCH AGENCIES IN ORDER TO ASSURE THAT PROPER CONSIDERATION IS GIVEN TO THE INTERNATIONAL IMPACT OF THE PROPOSED RULE.

QUESTION 27. ARE THERE FOREIGN SUPPLIERS OF RESEARCH AND TEST REACTOR HEU FUELS, AND IF SO, WHY WOULDN'T OTHER NATIONS BUY SUCH FUEL FROM THEM RATHER THAN UNDERTAKING THE EXPENSE OF CONVERSION?

ANSWER.

AT THIS TIME, THE U.S. IS THE PRIMARY SOURCE FOR HIGHLY ENRICHED URANIUM IN QUANTITIES SUFFICIENT TO MEET THE REQUIREMENTS FOR FUELING THE FREE WORLD'S RESEARCH AND TEST REACTORS. TO OUR KNOWLEDGE, NO OTHER COUNTRY HAVING THE CAPABILITY TO PRODUCE HEU (U.K., FRANCE, USSR, PRC AND SOUTH AFRICA) HAS MADE ANY EFFORT TO BECOME A MAJOR HEU SUPPLIER.

QUESTION 28. IS THE NRC PREPARED TO PROVIDE FUNDING TO EXPEDITE ANY SUCH CONVERSIONS?

ANSWER.

THE PROPOSED RULE INDICATES THAT FINANCIAL CONSIDERATIONS WILL BE WEIGHTED HEAVILY IN ESTABLISHING THE SCHEDULES FOR INDIVIDUAL FACILITY CONVERSIONS. THE COMMISSION BELIEVES THAT CONVERSION FUNDING FOR REPLACEMENT LEU FUEL, OPERATIONAL SUPPORT COSTS, AND LICENSING ASSISTANCE SHOULD CONTINUE TO BE PROVIDED THROUGH THE DEPARTMENT OF ENERGY OR OTHER GOVERNMENT AGENCIES. THE NRC, IN ITS REGULATORY ROLE, WILL, IF CONVERSION IS REQUIRED, DEVELOP GENERIC PROCEDURES THROUGH WHICH HEALTH AND SAFETY REVIEWS CAN BE ACCOMPLISHED IN AN EFFECTIVE, BUT EXPEDITED MANNER. THE NRC BELIEVES THAT ITS FUNDING OF CONVERSIONS WOULD BE INCONSISTENT WITH ITS STATUTORY ROLE AS A REGULATOR OF THE NUCLEAR INDUSTRY.

QUESTION 29. CAN ALL DOMESTIC RESEARCH AND TEST REACTORS CONVERT TO LEU FUEL AND STILL ACCOMPLISH ALL OF THEIR RESEARCH, PRODUCTION OR TEST GOALS? HAS THE NRC ASSESSED THE IMPACT OF ANY REDUCTION OF THESE GOALS, AND IF SO, WHAT ARE THEY?

ANSWER.

BASED ON THE PRESUMED CONTINUED SUCCESS OF DOE'S RERTR PROGRAM, ESSENTIALLY ALL DOMESTIC RESEARCH AND TEST REACTORS SHOULD TECHNICALLY BE ABLE TO CONVERT TO LEU OR REDUCED ENRICHMENT HEU FUEL. AS INDICATED IN THE RESPONSE TO QUESTION 17, CASE STUDIES ON A SMALL NUMBER OF RESEARCH FACILITIES WILL BE NECESSARY TO DETERMINE IF THEIR RESEARCH, PRODUCTION, OR TEST GOALS WOULD BE SIGNIFICANTLY IMPAIRED BY CONVERSION TO LEU FUEL. INFORMATION FROM THE RERTR PROGRAM INDICATES THAT THE IMPACTS CAN BE POSITIVE, REMAIN ESSENTIALLY UNCHANGED, OR BE NEGATIVE, DEPENDING ON THE SPECIFIC GOAL BEING ADDRESSED. IF THE CONVERSION SHOULD SIGNIFICANTLY IMPACT A PROGRAM GOAL, THE PROPOSED RULE PROVIDES FOR THE CONSIDERATION OF AN EXEMPTION BASED ON FOUR "UNIQUE PURPOSE" CONSIDERATIONS.

QUESTION 30. IF THE NRC ORDERS CONVERSION OF THESE REACTORS, HAS IT BEEN DETERMINED THAT ANY LICENSE AMENDMENTS WOULD BE NECESSARY?

ANSWER.

IF THE NRC REQUIRES BY RULE THE CONVERSION OF RESEARCH REACTORS USING HEU TO USE OF LEU AS FUEL, LICENSE AMENDMENTS WOULD BE NECESSARY IF THE EXISTING LICENSE DID NOT CONTAIN PROVISIONS AND CONDITIONS INCLUDING TECHNICAL SPECIFICATIONS SUFFICIENTLY BROAD, IN VIEW OF THE CONFIGURATION OF THE REACTOR, TO ENCOMPASS THE CONVERSION TO THE USE OF LEU. HOWEVER, AS NOTED IN THE ANSWER TO QUESTION 14, SUCH AMENDMENTS COULD BE ACCOMPLISHED THROUGH A RULEMAKING PROCESS.

QUESTION 33. WHAT WAS THE IMPETUS FOR THE COMMISSION'S DEVELOPMENT OF A RULE REQUIRING THE CONVERSION FROM HEU TO LEU FUEL?

ANSWER.

THE IMPETUS FOR THE COMMISSION'S DEVELOPMENT OF A PROPOSED CONVERSION RULE WAS BASED ON TWO MAJOR CONSIDERATIONS. THE FIRST WAS THE DESIRE TO IMPLEMENT THE ACTIONS CALLED FOR IN THE COMMISSION'S POLICY STATEMENT OF AUGUST 1982. THE STATEMENT WAS DIRECTED AT REDUCING PROLIFERATION RISKS ASSOCIATED WITH INTERNATIONAL INVENTORIES OF AND TRAFFIC IN HEU. THE SECOND CONSIDERATION WAS THE DESIRE TO MINIMIZE THE RESIDUAL RISK OF DOMESTIC THEFT OR DIVERSION OF HEU.

QUESTION 34. SEVERAL WITNESSES AT THE HEARING MADE REFERENCES TO THE DECISION TO CLOSE THE U.C.L.A. REACTOR AFTER THE UNIVERSITY HAD SPENT SEVERAL YEARS TRYING TO RELICENSE THE REACTOR. WOULD YOU PLEASE COMMENT ON THE U.C.L.A. LITIGATION? WHAT ISSUES WERE RAISED?

ANSWER.

IN 1980, A LOS ANGELES GROUP NAMED COMMITTEE TO BRIDGE THE GAP (CBG) FILED A PETITION TO INTERVENE IN RESPONSE TO THE COMMISSION'S NOTICE OF OPPORTUNITY FOR HEARING CONCERNING UCLA'S APPLICATION FOR A SECOND LICENSE RENEWAL FOR UCLA'S 100 KW ARGONAUT UTR. (UCLA'S ORIGINAL LICENSE WAS GRANTED IN 1960). AN ATOMIC SAFETY AND LICENSING BOARD GRANTED CBG INTERVENTION AND ADMITTED TWENTY ISSUES RAISED BY CBG FOR LITIGATION. THE ISSUES ASSERTED WERE: (1) THE RENEWAL APPLICATION WAS DEFICIENT, (2) UCLA MUST OBTAIN A COMMERCIAL LICENSE PURSUANT TO SECTION 103 OF THE ATOMIC ENERGY ACT RATHER THAN RETAIN THE 104 RESEARCH REACTOR LICENSE, (3) INADEQUATE MANAGEMENT OF THE REACTOR, (4) UNSAFE OPERATION OF THE REACTOR, (5) THE EXCESS REACTIVITY ALLOWED BY LICENSE WAS UNSAFE, (6) THE REACTOR EMITTED RADIOLOGICAL RELEASES IN EXCESS OF 10 CFR PART 20 LIMITS, (7) THE REACTOR WAS UNRELIABLE AND UNSAFE, (8) THE SAFETY ANALYSIS IN THE APPLICATION WAS INACCURATE, (9) THE REACTOR WAS NOT ADEQUATELY MAINTAINED, (10) AN ENVIRONMENTAL IMPACT STATEMENT SHOULD BE PREPARED, (11) SEVERAL

SAFETY FEATURES SHOULD BE ADDED SUCH AS A CONTAINMENT AND AN ECCS, (12) UCLA WAS ALLOWED TO POSSESS AN EXCESSIVE AMOUNT OF HEU, (13) UCLA SHOULD ANALYZE COMMON PROBLEMS OF ARGONAUTS, (14) THE REACTOR SITE WAS UNSAFE DUE TO DENSE POPULATION, (15) THE REACTOR WAS TOO OLD FOR SAFETY, (16) AN EARTHQUAKE COULD DAMAGE THE REACTOR, (17) THE UNIVERSITY OF CALIFORNIA WAS NOT FINANCIALLY QUALIFIED TO SAFELY OPERATE THE UCLA REACTOR, (18) SABOTAGE, AIRPLANE CRASH, MULTIPLE MODE FAILURES AND OPERATOR ERROR COULD CAUSE RADIOLOGICAL RELEASES, (19) THE UCLA SECURITY PLAN, AND (20) EMERGENCY PLAN WERE INADEQUATE.

LITIGATION BEGAN IN 1980 WITH DISCOVERY, WHICH CONTINUED UNTIL MAY 1983 WHEN THE FIRST OF SEVERAL HEARINGS ON SEVEN ISSUES WAS HELD IN LOS ANGELES. THE HEARINGS WERE NOT COMPLETED AND NO DECISION ON THE ISSUES HAD BEEN REACHED WHEN UCLA FILED ITS REQUEST TO WITHDRAW THE LICENSE RENEWAL APPLICATION AND TO TERMINATE THE LICENSE IN JUNE 1984. THE REQUEST FOR WITHDRAWAL IS PRESENTLY PENDING BEFORE THE LICENSING BOARD.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

January 15, 1985

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
United States House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

By letter dated December 17, 1984 the Commission forwarded responses to 28 of the 34 questions for the record of the hearing on Conversion of Research and Test Reactors to Low Enriched Uranium (LEU) Fuel. Responses to the remaining six questions are enclosed.

Since this hearing was conducted jointly by the Subcommittees on Energy Development and Applications and Energy Research and Production, we are also forwarding these responses to Chairman Marilyn Lloyd.

Sincerely,

Edward Fay

Carlton Kammerer, Director
Office of Congressional Affairs

Enclosure:
As stated

QUESTION 1A. Has the Department of State asked the NRC to promulgate a rule requiring conversion from HEU to LEU fuel? If not, why is NRC proposing to take action based, in large part, on foreign policy considerations?

ANSWER.

No. The proposed rule was issued as a follow-on to NRC's 1982 policy statement, which expressed NRC's plan to encourage that action be taken to eliminate U.S.-supplied inventories of HEU to the maximum degree possible, and to encourage further conversion efforts by foreign operators by taking appropriate regulatory steps to support similar conversion efforts by U.S. reactor operators.

While the Department of State did not ask NRC to promulgate this rule, the policy statement setting forth NRC's intention was fully coordinated with State and concurred in by State, on behalf of the Executive Branch, prior to issuance. State advised NRC, at that time, that the statement would be very useful in implementing the procedures under which U.S.-supplied inventories of HEU can be eliminated to the maximum degree possible. State also expressed the view that there should be a coherent policy respecting the use of HEU fuels in both foreign and domestic research reactors. With regard to the international implications of the proposed rule, the State Department has stated that it could have some "marginal effect" on future negotiations with foreign reactor operators on the need and timing for converting their own reactors.

In commenting on the proposed rule, State advised NRC that the criterion in the proposed rule for converting "unique purpose" reactors should be changed to exempt existing non-power lifetime core reactors, which were built before current concerns about HEU use surfaced. State noted that: (1) there are no significant nonproliferation benefits associated with conversion of lifetime core reactors since they do not add to HEU commerce, and (2) the suggested exemption would bring the domestic conversion program criteria in line with those for foreign research reactors.

QUESTION 1B. Please identify the domestic and foreign research reactors that (1) have converted to LEU fuel, (2) can now be converted to LEU fuel but haven't done so, and (3) cannot convert to LEU fuel because the technology has not been demonstrated.

ANSWER.

Based on information provided by the reduced enrichment for research and test reactors (RERTR) program at Argonne National Laboratory, it is technically feasible to convert a large fraction of non-power reactors from HEU to LEU fuel at the present time. However, the current limitations on fuel density could require major changes in fuel geometry and potential performance loss for many of the facilities. If the fuel development efforts, currently underway within the RERTR program, are successful over the next five years, the technical feasibility of converting almost all non-power reactors should be demonstrated. Furthermore, the need for changes in fuel configuration would be minimized while optimizing performance.

The Ford Nuclear Reactor at the University of Michigan and the OSIRIS (France) reactors have been fully converted to LEU fuels. Others, such as the University of Maryland and Pennsylvania State University, converted several years ago from plate-type HEU fuel to LEU TRIGA. A listing (provided by Argonne) of facilities now in the process of being converted to or testing prototype LEU fuel includes the following:

1.	RA-3	Argentina
2.	IEA-R1	Brazil
3.	JRR-4	Japan
4.	PRR-1	Philippines
5.	JEN-1	Spain
6.	TRIGA	Korea
7.	TRIGA	Mexico
8.	TRIGA	Austria
9.	TRIGA	Yugoslavia
10.	RP-0	Peru
11.	ASTRA	Austria
12.	FRM	Germany

Other reactors in the process of a two-step conversion from HEU to 45% enriched HEU and then to 20% LEU fuels are:

1.	SAFARI	South Africa
2.	LAREINA	Chile
3.	JRR-2	Japan
4.	JMTR	Japan
5.	SAPHIR	Switzerland
6.	KUCA	Japan
7.	JMTRC	Japan

QUESTION 1B (Continued)

Other reactors for which technical feasibility studies have yet to be completed are:

1.	HFR Petten	The Netherlands
2.	HFR Grenoble	France
3.	BR-2	Belgium
4.	R-2	Sweden

Technical constraints may prevent conversion of some of these reactors to LEU fuel if current performance requirements are to be maintained.

Conversion of almost all of NRC's domestic licensees, is, or is expected to be technically feasible if the RERTR program is successful over the next five years. A report prepared for the NRC by an LEU Study Group indicated that from 3-5 facilities could be converted with today's fuel technology without significant change in core thermohydraulics. The Report also identified the University of Missouri-Columbia and the Massachusetts Institute of Technology as the only university facilities in which conversion may not be feasible without loss of core performance. High density LEU fuels are under development which could replace HEU fuels in facilities such as the Union Carbide and National Bureau of Standards reactors. However, detailed conversion studies would be required to determine whether or not such a fuel replacement would have a significant impact on the missions of these or other non-university facilities.

Conversions of approximately 40 foreign low power (less than 1 MW) facilities, generally not included in the RERTR program conversion plans, are believed to be technically feasible.

Of the larger DOE facilities, the Oak Ridge reactor will be used as the facility to test a full core of high density LEU fuel. As Mr. Kane indicated in his testimony, initiation of conversion studies for the larger DOE facilities will be based on the progress made in demonstrating the feasibility of high density LEU fuels. The NRC is not aware of any plans to convert the lower power (less than 1 MW) DOE facilities.

QUESTION 4. Do you agree with Dr. Zebroski's comment that "reactors with lifetime cores, which nominally have much less than a kilogram [of HEU] on site, may be reasonably found to be exempt from [conversion]"?

ANSWER.

Research reactors with lifetime cores that use HEU fuel typically have more than one kilogram of HEU in the core (see also the answer to Question Number 6). The recently proposed rule published in the Federal Register would require conversion by reactor licensees with lifetime cores. The NRC is studying the appropriateness of this requirement in light of public comments (also, see the answer to Question Number 7).

QUESTION 16. Has there ever been either a successful or unsuccessful attempt to divert HEU fuel from a domestic research and test reactor?

ANSWER.

To our knowledge there has not been either a successful or confirmed unsuccessful attempt to divert HEU fuel from an NRC licensed research and test reactor. There is a case where 20 grams of HEU was missing but later was found at the facility following police questioning.

We are aware of an individual breaking into a university reactor site. The individual was subsequently arrested and convicted of breaking and entering. We are also aware of another report of an intrusion into a building housing a university reactor.

QUESTION 23.	The proposed rule defines LEU fuel as fuel in which the weight percent of Uranium-235 is less than 20 percent. What is the practical lower limit of LEU fuel before one begins to get a significant increase in plutonium production?

ANSWER.

There is no specifically defined limit of enrichment below which plutonium production becomes significant. Consideration of plutonium production depends on a number of variables including power level, operating cycle, as well as fuel enrichment.

The production of plutonium will be relatively higher in lower enrichment fuel. For example, a 20 MWth research reactor using 10 to 20% enriched uranium would generate about 0.5 kg. of plutonium per year. In contrast, a 20 MWth research reactor fueled by natural uranium would produce about 5 kg. of plutonium per year. A practical lower limit for plutonium production has not been established. However, it should be noted that HEU is directly usable for weapons purposes, while plutonium obtained from spent reactor fuel would require chemical processing of the reactor fuel to extract plutonium.

QUESTION 31. What has the Department of State told you about their position on this issue?

ANSWER.

In the issue of license amendments, the Department of State has commented that, based on its international experience with RERTR participants, the U.S. will need to be sensitive to licensing and funding issues associated with proposals to convert non-power reactors. We plan to take these factors into account in our review of the proposed rule.

On the issue of conversion in general, please see answer to Question 1A.

QUESTION 32. What has DOE told you about the availability of LEU fuel for all domestic research and test reactors?

ANSWER.

DOE has indicated that they are encouraging the medium power research reactors that refuel on a regular basis to consider conversion to the use of LEU fuel as HEU fuel is expended. Attempts are underway to develop a standard fuel plate which meets the needs of the affected facilities. DOE's Oak Ridge reactor will be used to test a full core of high density silicide fuel; however, as Mr. Kane of DOE indicated in his testimony, initiation of conversion studies for DOE facilities will be based on progress made in demonstrating the feasibility of high density LEU fuels.

Additional Questions for Mr. Ebersole

1. You indicated that you don't believe the proposed rule to convert to low-enriched uranium fuel should be tied to "an unidentified threat." Do you believe that the terrorist threat is a credible one for research and test reactors, and if so, why shouldn't potential terrorist activity be considered in any potential ordering of conversion to low-enriched uranium fuel?

2. What specific provisions do you refer to in the Nuclear Nonproliferation Policy Act of 1978 that would support converting domestic reactors to low-enriched uranium fuel?

3. You mentioned that new safety analysis would be prudent in ordering the conversion to low-enriched fuel. This would appear to be a hidden cost in the conversion of each research and test reactor. Has this been taken into consideration in cost estimates for the conversion?

4. You recommended that the Federal government pay the costs of conversion because it is principally necessary to satisfy a international nonproliferation effort. What do you estimate as the total cost for such conversions?

   Do you have any indication that other countries are ready to convert in the near future?

5. Do you support the proposed rule provided it is based on national policy?

6. What are we buying in terms of risk reduction in moving from HEU to LEU? What would be the benefit of moving to say the 50 percent level versus 20 percent or less?

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

October 16, 1984

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research and Production
Committee on Science and Technology
United States House of Representatives
Washington, D.C. 20515

Dear Madam Chairman:

We are pleased to transmit the ACRS response to the six questions identified in your letter dated October 10, 1984. We would like this information to supplement the testimony of Messrs. Ebersole, Mark and Remick at the September 25, 1984 hearing on the conversion of research and test reactors to low-enriched fuel.

We hope that this information will be helpful to the Congress in formulating a position on this matter.

Sincerely,

Jesse C. Ebersole

Jesse C. Ebersole,
Chairman

RESPONSE TO CONGRESSIONAL QUESTIONS

Q1. You indicated that you don't believe the proposed rule to convert to low-enriched uranium fuel should be tied to "an unidentified threat." Do you believe that the terrorist threat is a credible one for research and test reactors, and if so, why shouldn't potential terrorist activity be considsered in any potential ordering of conversion to low-enriched uranium fuel?

A1. We interpret the threat under discussion to be that of terrorist theft or diversion of explosive-capable nuclear material, since other forms of terrorist threat are not relevant to the conversion question. We believe the threat of such theft or diversion from research reactors is low, to the point of being barely credible if the object in question is an explosive device. If, however, the reduction of HEU use is national policy, that is a more defensible basis for action.

Q2. What specific provisions do you refer to in the Nuclear Nonproliferation Policy Act of 1978 that would support converting domestic reactors to low-enriched uranium fuel?

A2. We refer to the provision in §105 of PL 242 (the NNPA of 1978) in which it says, "The President shall take immediate initiatives to reevaluate all aspects of the nuclear fuel cycle, with emphasis on alternatives to ... plutonium ... or the presence of high enriched uranium ...."

Q3. You mentioned that new safety analysis would be prudent in ordering the conversion to low-enriched fuel. This would appear to be a hidden cost in the conversion of each research and test reactor. Has this been taken into consideration in cost estimates for the conversion?

A3. We had not supposed that new safety analysis constituted a "hidden" cost of conversion. The reactors will have been considered with HEU fuel and in almost all (if not all) cases it will be prudent -- if not required by the license -- that they be reconsidered in respect to time - temperature - flux variations, etc. if the fuel is changed. This has been given at least some consideration in the cost estimates presented in the NUREG/CR-3666, "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Encirched Uranium Fuel".

Q4. You recommended that the Federal government pay the costs of conversion because it is principally necessary to satisfy a international nonproliferation effort. What do you estimate as the total cost for such conversions?

Do you have any indication that other countries are ready to convert in the near future?

A4. Cost of conversion may be divided into several parts; namely: cost for the replacement reactor core, necessary equipment modifications transportation, etc.; cost due to possible lengthy licensing hearings; and cost because some experiments cannot be accomplished. While we did not determine replacement core and equipment modifications costs, others have (see NUREG/CR-3666). It is possible that the hearing costs can be avoided by statutory changes that would permit conversion without the necessity of a public hearing. We do not believe that it is possible to determine the cost due to changes in the experimental capability of test and research reactors. This cost will be site-specific and very dependent on the experimental programs in effect.

We have heard that at least some reactors in some countries are ready to convert when fuel supply arrangements can be put in effect. However, the State Department is in a much better position to discuss this than we are.

Q5. Do you support the proposed rule provided it is based on national policy?

A5. We support the implementation of national policy, but have reservations about the extension of that policy to these small research reactors if it does any substantial damage to research and education.

Q6. What are we buying in terms of risk reduction in moving from HEU to LEU? What would be the benefit of moving to say the 50 percent level versus 20 percent or less?

A6. The amount of uranium required to pose a hypothetical risk increases as the enrichment is reduced: nearly three times more 50 percent fuel would be needed to produce an explosive device than fuel of 90 percent enrichment, while the amount of 20 percent fuel needed would be more than ten times larger than the amount of 90 percent enriched fuel. The handling of these larger amounts of material will, of course, increase the difficulty of producing a device. At the same time, it should be noted that reduction of the enrichment of the fuel used in a reactor results in an increase in the quantity of uranium (and even in the Quantity of U-235) stored in the reactor. However, as already indicated, we consider this risk to be small in any case.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

October 10, 1984

Mr. Edwin L. Zebroski
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

Dear Mr. Zebroski:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

DON FUQUA, Chairman
Committee on Science
and Technology

MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Mr. Zebroski

1. You noted that there is "no urgent need" to convert to low-enriched fuel. Do you believe there is any need to convert to low-enriched fuel?

2. You statedd that "augmented security measures" can substitute for a conversion rule. Are such augmented security measures necessary because security at the present time is inadequate?

3. You mentioned a higher enrichment of 50% as an alternative to the less than 20% enrichment now considered appropriate for low-enriched fuel. Do you know why the 20% level was originally elected as the goal for LEU fuel? If so, please explain.

4. Would processing of the HEU fresh and irradiated fuel be necessary in order to use the material for a nuclear explosive device?

5. If conversion to LEU is ordered, would it be appropriate to consider exempting all those reactors with lifetime cores?

6. You statedd that it take would the amount of uranium-235 in several of the research reactors, possibly as many as five, to make a single "low technology" nuclear explosive device. What about a high technology device?

7. What leverage does the U.S. have in insisting that the HEU existing at foreign sites be returned? Are there even good records of where this material is?

8. How would you rank the risks of diversion of HEU from domestic research and test reactors relative to other HEU sources?

9. What are the potential threats to reactor facilities? How would conversion from HEU to LEU address these threats?

10. What are some of the societal impacts of the loss of some research reactors?

11. What changes would you recommend to decrease the diversion risks at university reactors?

EPRI
Electric Power
Research Institute

October 30, 1984

Dr. Harlan L. Watson
Room D-374
Rayburn House Office Bldg.
Washington, D.C. 20515

Subject: Response to Questions in October 10 Letter on HEU-LEU, from Committee on Science and Technology

Dear Dr. Watson:

1. Question: Is there any need to convert to low-enriched fuel?

Answer: On the basis that public interest is served by addressing the largest risks first and expending resources in proportion to the size of the risk reduction achieved, I would suggest the following priorities:

1. Return of the substantial tonnage of spent fuel containing highly enriched U-235 to the United States.
2. Reduction in enrichment of fuel shipped overseas to no more than 50% U-235 (in 1-3 years).
3. Eventual reduction of fuel shipped overseas to about 20% enrichment (in 3-6 years).
4. Conversion of domestic research and testing reactors with power ratings in excess of 5 megawatts to about 50% enrichment when such fuel becomes available (in 3-6 years) and replacement is needed.
5. No scheduled conversion and enrichment of low power research reactors which have "lifetime cores" until and unless fuel replacement becomes necessary for operational reasons, in that case, enrichments of 50% or less could be used. These priorities recognize the ranking of diversion risks as developed in the attached paper*.

*"Analysis of Diversion Risks of Plutonium or Highly Enriched Uranium", E.L. Zebroski; Presented at Annual Meeting of The Society for Risk Analysis, Oct. 1, 1984.

2. Question: Are augmented security measures necessary because security at the present time is inadequate?

Answer: Security has been adequate historically since there has been no successful attempt at diversion or theft of research reactor fuel in nearly 1500 reactor years of existence of such reactors. (Although at least 3 minor intrusion attempts have occurred.) However, the NRC took substantial steps to upgrade security in 1983, and proposed still further augmentation in 1984 (following a Presidential directive to all Federal Agencies.) The augmented measures contemplate widespread use of tamper-resistant alarms and communications, some of which I understand are already implemented in many places. I believe that if these measures were uniformly implemented at all research reactors they would be adequate. I am not personally aware whether such implementation has been universally accomplished or not.

3. Question: Do you know why the 20% level was originally elected as a goal for LEU fuel?

Answer: I do not know the official reason for picking that level. Technically one can surmise that it was based on the increase in amount of material required, and the substantial increase in technical difficulty of making an explosive device work, as the enrichment is reduced. Many hundreds of kilograms would be required at 20%. I suggested the 50% enrichment level would be adequate for small research reactors and for larger overseas research and test reactors for two reasons:

A. Where such conversion is justified it is technically feasible to implement it 3-5 years sooner and with much higher assurance of adequate fuel performance, than with 20% enrichment.

B. With 50% enrichment or less, it would be necessary to postulate as a credible diversion hazard that the fuel from nearly all of the domestic research reactors was simultaneously diverted or stolen, in order to make even a single nuclear device possible.*

4. Question: Would reprocessing of HEU fresh and irradiated fuel be necessary in order to use the material for a nuclear explosive device?

Answer: Yes, reprocessing would be required for both types of material. However, for fresh fuel, the reprocessing could be done in conventional chemical facilities without shielding, whereas irradiated fuel requires more complex and expensive facilities to cope with the radiation levels present.

5. Question: Would it be appropriate to consider exempting all those reactors with lifetime cores?

Answer: Yes. This question is adressed more fully in the response to question number(1). (Second part of question on the the amount of material required for a "high technology" device.) High technology devices involve 10-20 kilograms of U-235 in the form of metal. The typical research reactor with lifetime core operates with less than 5 kilograms of HEU. Accordingly, even for high technology devices, from two to four research reactor inventories would be required assuming no losses in processing, and as a practical matter three to five typical research reactor inventories would be required.

6. Question: What leverage does the U.S. have in insisting that HEU existing in foreign sites be returned? Are there even good records of where this material is?

Answer: At present the U.S. makes substantial charges for receiving and reprocessing the material, including the cost for eventual storage for the radioactive wastes. These charges, I believe, are set on a "full amortization basis" which implies that the reprocessing and waste disposal facilities are amortized with a short life time leading to high charges per unit of fuel received. In addition, the sending country must bear the cost of packaging and shipping. The net effect of this is that there is little or no incentive to return the spent fuel because of the high costs. It would be in the national interest, and extremely cost-effective in investment of taxpayer money in terms of risk reduction, to charge at most the actual marginal operating costs only for reprocessing and waste disposal since the amortization costs are actually fully "sunk" costs. Also, reasonable credit for the value of the U-235 recovered can be a substantial offset to the cost of reprocessing. For many countries this would be sufficient leverage to motivate the return of spent fuel. In cases in which this was not effective, normal diplomatic pressures and economic incentives could be used to encourage the return of HEU. In respect to location of these materials, my understanding is that the IAEA maintains records for all or most of the countries involved and the NRC and DOE have been improving their access to such record keeping. I suspect the main deficiency is slow reporting of transactions involving intermediate transfers of such fuel in past years.

---

*Dr. Carson Mark, formerly in charge of weapons design at Los Alamos also endoresed consideration of enrichments near 50% for this purpose.

7. Question: How would you rank the risk of diversion of HEU from domestic research and test reactors relative to other HEU sources?

Answer: This question is covered under question number (1) and the reference listed. The actions (1), (2), and (3) in the reply to Question 2 address a risk about ten times larger than (a) in action (4). Action (4) addresses a risk about ten times larger than that in item (5).

8. Question: What are the potential threats to reactor facilities? How would conversion from HEU to LEU address these threats?

Answer: The threats to research facilities generally, are not restricted to research reactors. These include threats of damage to equipment, theft of materials or equipment, injury to personnel, and damage to facilities. In addition, symbolic actions for media attention, ranging from graffiti to vandalism to pointless damage, have occurred in some types of research facilities, such as computers. (These have not actually occurred at research reactors, however, to my knowledge.)

The conversion from HEU to LEU does not address most of these threats except for the possible theft of material. Conversion to LEU has the advantage that officials could say, in the event of theft, or attempted intrusion or thefts, that there is no possibility of making a nuclear explosive. However, the same statement could be made with HEU if the inadequate amounts of material at any research reactor are taken into account.

9. Question: What are some of the societal impacts of the loss of some research reactors?

Answer: One can speculate on the kinds of impacts, but the quantitative extent would require considerable studies. It would depend upon how many and which reactors were affected. Clearly there would be loss of both research (medical, physical, and chemical research) and training capabilities. The long term effect would be to move the center of gravity of such capabilities even more rapidly overseas with negative long term consequences in health, research, and training.

10. Question: What changes would you recommend to decrease the diversion risks at university reactors?

Answer: (Summing up from previous questions).

1. Assure comprehensive implementation of 1983 and 1984 security measures, including general implementation of modern tamper-resistant alarm and communication capabilities.
2. Provide for direct communication from research reactor facilities to Department of Energy emergency response teams. (The present system involves a chain of at

least four telephone calls, between different agencies. This guarantees excessive delay in useful response by DOE in the event such response were needed. (This single change, available at very low cost, probably gives a greater degree of risk reduction than all of the other measures so far considered. It faces the obvious obstacle of jurisdictional questions between various agencies.)

3. For the two or three research reactors which have significant power levels and operating factors that fresh fuel is frequently required, consider a gradual transition to 50% enrichment, or thereabouts, over a period of some years as in when such fuel becomes available and adequately tested.

4. For "lifetime core" reactors, implement the security steps discussed above, but do not mandate conversion to LEU. If fuel replacement eventually does become necessary, consider use of enrichment near 50%.

Thank you for the opportunity to respond to these questions.

Sincerely yours,

E. L. Zebroski

E. L. Zebroski
Chief Nuclear Scientist

ELZ/nw

Attachment: SRA Paper

EPRI
Electric Power
Research Institute

November 7, 1984

Dr. Harlan L. Watson
Room D-374
Rayburn House Office Bldg.
Washington, D.C. 20515

Subject: Revisions to October 30, 1984 "Response to Questions in October 10 Letter on HEU-LEU, from Committee on Science and Technology"

Dear Dr. Watson:

Enclosed is a copy of subject letter with several revisions and/or corrections. This copy supercedes the October 30th version.

Sincerely,

E. L. Zebroski (nw)

E. L. Zebroski
Chief Nuclear Scientist

ELZ/nw
enclosure

EPRI
Electric Power
Research Institute

REVISION: November 6, 1984
October 30, 1984

Dr. Harlan L. Watson
Room D-374
Rayburn House Office Bldg.
Washington, D.C. 20515

Subject: Response to Questions in October 10 Letter on HEU-LEU, from Committee on Science and Technology

Dear Dr. Watson:

1. Question: Is there any need to convert to low-enriched fuel?

Answer: On the basis that public interest is served by addressing the largest risks first and expending resources in proportion to the size of the risk reduction achieved, I would suggest the following priorities:

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A. Where such conversion is justified it is technically feasible to implement it 3 to 5 years sooner, and with much higher assurance of adequate fuel performance, than is the case with 20% enrichment (for some reactors.)
B. With 50% enrichment or less, it would be necessary to postulate as a credible diversion hazard that the fuel from nearly all of the domestic research reactors was

simultaneously diverted or stolen, in order to make even a single nuclear device possible.*

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Answer: Yes, reprocessing would be required for both types of material. However, for fresh fuel, the reprocessing could be done in conventional chemical facilities without shielding, whereas irradiated fuel requires more complex and expensive facilities and greater technical sophistication and experience to cope with the radiation levels present.

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Answer: Yes. This question is adressed more fully in the response to question number(1). (The second part of question is on the the amount of material required for a "high technology" device.) High technology devices involve 10 to 20 kilograms of U-235 in the form of metal. The typical research reactor with lifetime core operates with less than 5 kilograms of HEU. Accordingly, even for high technology devices, from two to four research reactor inventories would be required assuming no losses in processing, and as a practical matter three to five typical research reactor inventories would be required.

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Answer: This question is covered under question number (1) and the reference listed. The items numbered (1), (2), and (3) in the reply to Question 1 address a risk about ten times larger than the risk which item (4) addresses. Item (4) addresses a risk about ten times larger than that in item (5).

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10. Question: What changes would you recommend to decrease the diversion risks at university reactors?

Answer: (Summing up from previous questions).

1. Assure the comprehensive and continued implementation of 1983 and 1984 security measures, including general implementation of modern tamper-resistant alarm and communication capabilities.
2. Provide for direct prompt capability for communication from research reactor facilities to the Emergency Response teams maintained by the Department of

Energy. (The present system involves a chain of at least four telephone calls, between different agencies and six different locations. This procedure guarantees excessive delay in useful response by DOE in the event such response were to be needed. (This single change in communication capabilities, available at very low cost, probably gives a greater degree of risk reduction than all of the other measures so far considered. It faces the obvious obstacle of jurisdictional questions between various agencies.)

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Thank you for the opportunity to respond to these questions.

Sincerely yours,

E. L. Zebroski

E. L. Zebroski
Chief Nuclear Scientist

ELZ/nw

Attachment: SRA Paper

EPRI

ANALYSIS OF RISKS OF DIVERSION OF PLUTONIUM OR HIGHLY ENRICHED URANIUM

E. L. ZEBROSKI
ELECTRIC POWER RESEARCH INSTITUTE
3412 HILLVIEW AVENUE
PALO ALTO, CALIFORNIA 94303

Presented at the Annual Meeting of
The Society for Risk Analysis
October 1, 1984
Knoxville, Tennessee

Presented at the Annual Meeting of The Society for Risk Analysis - October 1, 1984 Knoxville, Tennessee

ANALYSIS OF RISKS OF DIVERSION OF PLUTONIUM OR HIGHLY ENRICHED URANIUM

E. L. Zebroski
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94303

ABSTRACT

The production of a nuclear explosive device requires a range of specialized skills and facilities and a sufficient quantity of concentrated fissionable material. Significant amounts of such materials exist in hundred of locations, in a variety of forms including mixtures with nonfissionable materials and with radioisotopes. Nuclear weapons start with pure metallic materials of predominantly a single isotope (uranium-235 or plutonium-239). Chemically or isotopically diluted materials either require larger amounts of fissile isotope or else cannot be made to produce an explosive reaction without extensive processing involving sophisticated techniques and facilities. Obstacles to diversion of fissionable materials include combinations of physical security, guards and defense forces, accountancy, diluents, limited amounts of material in any one location, and timely detection and forceful reaction to attempts at diversion or theft.

A generalized risk assessment model is developed, incorporating the main factors that influence the probability of successful diversion. A roughly inverse relationship is involved between the amount of material potentially seized or diverted and the levels, skills, facilities, and resources required to make a workable nuclear device. Absolute probabilities are indeterminate. Experience indicates an upper bound of about 1.6×10^{-6}/year/weapon-equivalent amount of material. Inequality relationships can be used to develop relative rankings and semiquantitative magnitudes of diversion risks.

Small university research reactors appear to contribute less than 0.1% of the total diversion risk of U.S. materials. Limiting the amounts of material at any one university location is practical so that thefts from several--perhaps half a dozen--reactors would be required to make a single explosive device plausible.

A related, nonnuclear risk appears relatively likely, arising from the likelihood of unwarranted public overreactions to a variety of actions from vandalism to attempted thefts. These reactions are likely, given the present levels of discrimination on this topic.

Cost/benefit relationships are also derived. These exhibit disparities of several orders of magnitude in the ratios of commitments made or planned to the size of risk exposure reductions attainable.

KEY WORDS: Diversion; Weapons-Material;-Nuclear Bombs; Research Reactors; U-235; Plutonium.

Probabilistic Formulation of Risk Exposure

The main factors which affect the likelihood of successful diversion, or theft of material to the end result of a workable nuclear device are exhibited in equations (1) through (4).

$$P_{tot} = {}_{i,t} \quad P_{i,t} \; T_i \qquad \text{(Eqn. 1)}$$

$$P_{i,t} = \frac{d_{i,t} \; A_{i,t}}{M_b} (1 - r_{i,t}) \; Q_{i,t} \qquad \text{(Eqn. 2)}$$

P_{tot} = Total probability of successful diversion of material from all i facilities in time interval t.

$P_{i,t}$ = The probability of successful diversion of material to produce n workable nuclear explosive devices from location i, in time interval t.

$A_{i,t}$ = The amount of weapons-usable material contained in location i, during time interval t.

M_b = The mass of fissile material required for a nuclear explosive device of type b.

$d_{i,t}$ = The probability of accesss for theft or diversion from location i in time interval t, of amount $A_{i,t}$.

$r_{i,t}$ = The probability of detection and protection or recovery of material $A_{i,t}$ given that access has occurred or been attempted.

$Q_{i,t}$ = The probability of success in assembling a workable nuclear device given mass M_b.

T_i = Time of exposure of amount $A_{i,t}$ at location i.

There is a further important relationship affecting the value of M_b for a given diversion attempt

$$M_b = \frac{M_o}{f(R,S,D,E,G,T)} \qquad \text{(Eqn. 3)}$$

where M_o = just critical mass of material without efficient reflector and at nominal density

f(R,S,D,E,G,T) = a complex relationship generally proportional to the product of the availability of resources R, Scientific and technological skills S, specialized data D, specialized equipment and facilities E, specialized materials G, and time T, available to accomplish the design, processing, testing, and assembly.

Also $Q_{i,t}$ f(R,S,D,E,G,T) (Eqn. 4)

And for $M_b \ll M_o$; $Q_{i,t} = R \times 10^{-9}$

where R = resources in $

The expressions given can not be quantitatively evaluated in closed form. However, they permit several of order-of-magnitude qualitative or ranking comparisons that can be useful in decisions on risk management activities.

Assumption of a First Law of Risk Management

The value of these inequalities assumes their use in the ideal mode of rational risk management to optimize the total amount of safety which is obtained for the total effort available or expended. This might be referred to as the "first law of risk management," which can be formulated as follows: "the relative effort applied to limit or control a given risk should be in proportion to the product of the relative size of the risk and the fractional reduction in that risk achievable for the effort applied."

It is recognized that such a first law is very limited in real world application for several reasons. The discipline for establishing relative risks within a given field of or type of risks is now often practical, but is used only sporadically in practice. The problem of developing relative risks between different areas or functions of society, is still in its infancy, is overlaid with subjective values and customs, and has virtually no impact in public risk management and policy. Exogenous factors commonly drive the priority and resources devoted to risk management activities of various types. The extended literature on the influence of risk perception highlights the large gaps between rational deployment of effort in risk management and actual current practices. This analysis adds to the literature of such gaps.

Recognizing all of the foregoing limitations, nevertheless, it is assumed that awareness of the relative rankings of risk exposures to a common set of hazards can be useful to policy makers and in-drafting specific rules, regulations, and procedures which indicate the type and intensity of efforts to be applied to various risk management activities.

Effects of the Controlling Factors

The general relationship equation (1) can be interpreted as a measure of the annual probability that significant amounts of fissionable material might be seized, stolen, or diverted, from locations holding such materials, and in amounts sufficient to produce one or more nuclear explosives. Recent attention on improvement in security measures in certain weapons storage facilities are aimed at reducing the probability of success of access ($d_{i,t}$). However, a little reflection will suggest that vaults or passive measures can always be breached if the incentive is large enough, and that the factor ($r_{i,t}$) of detection, recovery and reaction forces is at least equally important in preventing successful theft or diversion.

Another factor, ($Q_{i,t}$), is extremely important in evaluating risks at locations at which only small amounts of material are present. Given a relatively large amount of material, an explosion with some degree of nuclear yield might be produced, perhaps not as a garage operation, but certainly with the materials and equipment available in almost any modern university with science and engineering departments. For this reason, much more intensive protective measures (affecting $d_{i,t}$ and $r_{i,t}$) are appropriate for facilities which routinely contain many times the amount of material (M_b). Given 50 or more kilograms of highly enriched U-235, it becomes plausible that an adequately educated but inexperienced team of people could produce a single nuclear explosive. To be sure, the reliability of the device might be uncertain, the yield might range anywhere from ability to destroy several city blocks to a nuclear "fizzle" with a nuclear yield hardly more than the chemical explosive used. Nevertheless, even such a primitive device could have major public and governmental impacts. For perspective, it should be noted that similar capacity for blackmail, terror, or damage can be obtained with much smaller initial resources and using much more readily available materials and means.

With smaller quantities of highly enriched U-235, say 20 to 30 kg, (or more to allow for processing losses), somewhat higher levels of skills and facilities are required, and there is greater need for specific physical data and calculations and process information for which the essential know-how is not available in the open literature. Unless it is further assumed that a sizeable team of people with extensive experience in a national weapons program are available, the time required to attain a plausibly workable device, and the probability of failure, both increase substantially.

For still smaller amounts of material, say 10 to 20 kilograms of U-235, net after processing losses, the requirements are sharply increased for specialized skills, data, facilities, and materials. As far as can be deduced from the historical record, this stage of development in each of the weapons countries has required an all-out national effort with essentially unlimited financial and material resources. Total times on the order of three years or more were required for a first successful effort in each of the countries which are currently weapons producers. The focus on the production of fissile materials tends to overlook the parallel, and in some respects more difficult developments required to produce the actual device.

The replication of such results by a team with all of the relevant data and experience, obviously would take less time and effort. However, it is highly implausible that a limited team of people with subnational levels of skills, resources, and facilities could accomplish this task in a short period of time. Three to five years can plausibly be regarded as being a minimum to achieve an appreciable probability of success.

The well-publicized assertions by a former Los Alamos employee that small amounts of materials could readily be converted to nuclear weapons given readily available unclassified data, skills, materials, and facilities, appears to have hidden within it several interesting assumptions. The most basic assumption required (to give a significant probability of success) is that a substantial team of people with a wide range of theoretical, engineering, chemical, metallurgical, and mechanical skills and directly applicable experience are available--presumably recruited from a national weapons laboratory such as Los Alamos--and that they willingly cooperate in a clandestine subnational or terrorist effort. A second assumption is that such a team would bring with it a large volume of detailed physical data, and nuclear, chemical, metallurgical, and specialized know-how, including explosives and hydrodynamic technology. A further hidden assumption appears to be that resources, and facilities--often estimated to be in the range of several hundred million dollars--are available to such a team, and that no obstacles in procurement, or hazards of detection of such activities are operative. For the case of limited amounts of fissile material requiring highly sophisticated design, fabrication, assembly, and packaging, the probability $Q_{i,t}$ can be represented as a judgment approximately by the product of resources available in dollars times 10^{-9}, and three to five years' time.

Alternate Paths and Diversion Scenarios —

For plutonium-239 as the target material for theft or diversion, many of the same considerations apply, except that the reference mass of material M_b is less than 1/3 as large as for U-235. This highlights an interesting strategic question on the motives and tactics of a would-be diverter. If weapons of medium or high technology, are desired, able to work with relatively small masses of material, then diversion of small amounts of material (say less than 50 kg of U-235) is unprofitable, relative to the overall effort required. A more direct, secure, and expandable route is the development of dedicated facilities to produce U-235 by any of a considerable number of proven enrichment processes. Equally simple, at this level resources, is the production of plutonium in a low-temperature, low-technology production reactor. The scenarios which lead to substantial prospects of success in diversion can be qualitatively ranked as follows:

(1) A national decision to "go for nuclear weapons" by seizure of substantial stockpiles of existing nuclear weapons already produced by one of the present nuclear weapons countries, and stored and deployed in several hundred locations throughout the world.

(2) A national level decision to "go nuclear" by clandestine development of as much as possible of the theory and technology of the device in a secret manner, followed by seizure of major amounts of fissile material (for U-235 ranging from several hundred to several thousand kgs) which may be available in aggregate as raw material, fabricated fuel, and spent fuel associated with research and testing reactors. Under similar circumstances, an alternate decision may be to seize substantial tonnages of spent fuel from power reactors, with the intention of reprocessing to extract plutonium, using previously built and tested facilities. Both of these options involve large risks of international interventions.

(3) A national, but more likely subnational, faction decision to seize relatively small amounts of material (for example, 25 to 100 kgs of U-235) which may be available in research testing, or prototype reactors.

(4) Subnational factions or terrorist groups' decision to steal or divert relatively small amounts of material from fabrication stockpiles, or research and test reactors for criminal, terrorist, or ideological ends.

(5) Diversion or theft of material from U.S. medium or high-powered research or test reactors.

(6) Diversion or theft from low-powered U.S. research reactors commonly at universities.

We note that each scenario involves somewhat different objectives, requirements, and resources. It is important in assessing risks of various scenarios to use self-consistent sets of assumptions. For example, a highly skilled, highly resourced group with near-national capabilities would have little motivation for thefts of small quantities of material, since this would rate poorly relative to a self-production approach or relative to seizure from locations with large amounts which could be expanded to a significant offensive or defensive capability.

Limiting Value Approach to Aggregate Historical Exposure

A large number of nuclear weapons are deployed in several hundred locations within the United States. All but three states are known to have several such locations. In addition, weapons are deployed in over 100 locations in Europe, and several hundred locations in Southeast Asia, not counting ships at sea. Given the buildup of production of nuclear warheads (including aircraft-carried bombs, artillery shells, and warheads for ballistic and cruise missiles), something in excess of 30,000 such devices have been produced in the United States and stockpiled or deployed. Allowing for the buildup over time since 1945, we can estimate a cumulative exposure of approximately $4x10^5$ weapon-years has occurred. We can take account of raw material and material in production and rework pipelines by dividing the amount of such materials by the average mass required for a weapon. This gives a further estimate of $2x10^5$ weapons-equivalent years of exposure. Similarly, we can estimate the exposure for non-weapons materials in several categories. For example, highly enriched materials supplied for research in test reactors overseas are approximatley $1.5x10^4$ weapon-years equivalent. Domestic research and test reactors (medium and high power) constitute about $1.5x10^3$ weapon-year equivalent. Small low-powered university type research reactors give a cumulative exposure of less than $4x10^2$ weapon-year equivalents.

The overall cumulative exposure is roughly $6x10^5$ weapon-years exposure to date. Given that no successful diversion resulting in a nuclear device has occurred, the current limiting value for diversion or theft is about 1.6×10^{-6} per weapon or weapon equivalent, per year.

Derived in the same fashion, the current annual exposure is approximately 4×10^4 weapon-years per year. If the historical cumulative value is taken as an approximation to the expected value, then the overall exposure of the entire inventory leads to a current value of $P_{tot} = 0.06$ per year. This number declines slowly with time assuming the favorable experience to continue. Nevertheless, it is not entirely comforting, since it leads to a 50% expectation of a successful diversion in about 12 years.

The foregoing discussions of the historical record is neutral to the differences in the values of the controlling variables as exhibited in equation 2. For practical decision-making purposes it is necessary to examine at least the order-of-magnitude differences in the controlling variables between the different segments of exposure.

Factors Controlling Weapons Diversion Exposures. It is evident that the preferred target for a would-be diverter, whether national, subnational, or terrorist, would be an actual weapon. Actual weapons represent over 96% of the weapon-years exposure to date, yet there apparently has been no actual diversion, nor even a competently mounted threat of such diversion evident.

Weapons storage locations are protected by vaults and guards. If the statistics of successful breaches of bank vaults applied; one would expect to have seen several dozens of occurrences. Evidently the factor of detection and reaction ($r_{i,t}$) is quite large. The presence of armed guards and barriers of the military installation are certainly significant obstacles. However, under some circumstances such obstacles could be relatively minor to a determined band of attackers, as for example, when weapons or weapons material are being transported by truck, train, or aircraft. The dominant protective factor operating, we may surmise, is the high assurance of detection and reaction, with indefinitely increasing force if necessary.

The probability factor of achieving the successful fabrication of a nuclear device ($Q_{i,t}$) is relatively high for weapons, but not unity as might be supposed. Weapons have defensive features such as separate keys of unique materials, and certain self destruct capabilities, which prevent them from being useful to an adversary who might capture them in a battlefield situation. For the same reason, even a successful peacetime diversion would still require a high degree of technical sophistication, and preferably a variety of detailed technology knowledge accessible only to "insiders", if $Q_{i,t}$ is to attain values as high as 0.1 to 0.5, and given limited periods of time, of the order of several months.

Overseas Exposure of U.S.-Supplied High Enriched Uranium. Approximately 18,000 kilograms of this material have been supplied to countries overseas (1). For various reasons, the United States did not establish a pattern of tracking this material point by point and moment and moment but relies on either bilateral agreements or IAEA accountability and inspection. At a any given time, up to 2,000 kg. of such material is present overseas as raw material (uranium metal, uranium hexafluoride, or uranium oxide) or as material undergoing fabrication processes and including fabricated fresh fuel.

Something in the range of a half of a ton of such material is present at any given time in operating reactors, where it has associated with it the high levels of radioactivity of operating nuclear fuel. By far the largest part of this material exists in spent fuel pools scattered in roughly 100 locations, in 40 countries, with the bulk of it in Western European countries and Japan. Allowing for the elimination of some U-235 by burnup in the fuel, and the relatively small amount which has been returned to the United States for reprocessing, a rough estimate of 6,000 to 10,000 kgs. of highly enriched U-235 remains.

From a diverter's standpoint, the resources, skills and facilities required are substantially higher for radioactive fuel which might be taken from an operating reactor than for unirradiated fuel or raw materials. The highly radioactive fuel from the reactor core has the further disadvantage that attempts to remove or transport it can be detected at long distances by conventional radiation detectors, so that the likelihood of effective detection, reaction and recovery can be very large (provided that such functions are planned and implemented in a given region).

Spent fuel from fuel storage pools still requires substantially more difficult and complex processing than unirradiated fuel or raw material. However, the level of radiation emitted falls off inversely with time (approximately) so that detection at a distance after 1 year and 10 year storage is orders of magnitude less sensitive than for fuel recently removed from an operating reactor.

Medium and High-Powered Test reactors in the United States

Most of these reactors are operated by the Department of Energy and are located at national laboratories or weapons laboratories and associated facilities. In aggregate, these reactors involve similar amounts of material (within factors of 2) to the medium and high-power test reactors overseas. However, the effective exposure is an order of magnitude smaller than for the overseas reactors, since the spent fuel is routinely returned for processing, and returned to locations with military grade levels of protection and reaction forces. There appear to be no plans to convert domestic research and test reactors operated by the Department of Energy to lower enrichments.

Research and Test Reactors - Low Power

Over 50 low-power research and test reactors are operable within the United States, and roughly 30 of them involve some high enriched U-235 fuel. Most of these reactors have "lifetime cores" since the power level and duty cycle will take at least 20 years to reach the physical burn-up limits of the fuel. Many of these reactors are licensed to carry as inventory substantial additional amounts of unirradiated fuel, either as fresh fuel or as spent fuel awaiting shipping and storage. Augmented security procedures brought into effect in 1983 have largely eliminated the inventory of unirradiated fuel (or else provided for its storage at a DOE facility). With these measures, the amount of inventory at a typical university research reactor facility is less than 5 kg. and for some reactors less than 2 kg. A would-be diverter would have to remove and recover the material from at least three reactors to achieve some probability of producing a "high technology" device, and from at least half a dozen research reactors in order to have some chance of producing a "low technology" device. Nevertheless, of NRC has a draft rule pending which would require the conversion of all remaining non-DOE research reactors to low enrichment under 20% U-235 (2).

A decision was reached in the late 1970s that the continued shipment of tonnage quantities of highly enriched U-235 overseas constituted an undesirable risk, particularly since assurance of low values of $d_{i,t}$, or high values of $r_{i,t}$ could not be assured. Quantites of material $A_{i,t}$ at single locations range from several to many "low technology" nuclear devices. The process of conversion to low enrichment for exports is underway. However, the technical obstacles to producing high performance fuel at 20% enrichment (without substantial redesign of the reactor facility), are delaying implementation of this change to the late 1980s.

The conversion of domestic non-DOE research reactors is being proposed as a risk reduction measure, apparently for two reasons; (1) to further reduce the already small risk that successful diversion simultaneously from a number of reactors might result in a single nuclear device, and (2) to "set a good example" for overseas research and test reactors community (who have objected to the substantial increases in costs and loss of performance and reliability associated with the lower enrichment fuels*).

Measures of Cost Effectiveness of Risk Management Options

Substantial increments in physical security and presumably in detection and recovery forces have been implemented for military stores of weapons and weapons materials in recent months. These actions appear to be in response to the impacts of the terrorist bombings in Lebanon and elsewhere, and a general White House directive to augment physical security measures for facilities of all kinds. This appears to be a cost-effective approach, since nearly all of the people involved are already federal or contractor employees, so the main effect is to assure that effective plans and communications are organized.

COST EFFECTIVENESS OF CONVERSION TO LOW ENRICHMENT

The federal costs (mostly R&D) for conversion of overseas reactors are of the order of $30 to $50 millions. By the late 1980's this action will reduce the continuing inventory of high enrichment uranium in reactors and in the production pipeline by more than two tons.

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*Some overseas research reactor operators, mostly in government facilities, have objected that the conversion of university research reactors is meaningless as a "good example" since the medium and high powered and test reactors operated by the DOE are not affected.

The cost of this improvement to the U.S. is about $20/gram of material removed from service (not counting the procurement and conversion costs incurred overseas).

This strategy avoids increasing the continuing diversion risk exposure from the tonnage of spent fuel in storage pools, but does nothing to decrease it. This remains by far the largest store of weapons-useable U-235 not in U.S. custody. Overseas holders of this material are deterred from returning it to the United States since it costs them more than retaining it in storage pools. (The United States is prohibited by the NNPA of 1978* from expending any funds for receiving, storing, or processing any kind of spent fuel from overseas, but a year-to-year exemption for high enrichment fuel has been decreed).

On the current course of events, the cost vs. risk reduction benefits in vogue are shown in Table 2. The U.S. costs committed per gram removed from service (ideally a rough measure of assigned risk-reduction value), are actually in reverse order of the size of risk exposure. The most curious disparity is the effective assignment of a negative value to the dominant residual diversion risk of this type, namely the spent fuel tonnages overseas, which contain several hundred weapon equivalents.

The diversion risk ($d_{i,t}$) refers to the probability of removal of a weapons-usable amount from a given location (see equation 2). The likelihood of theft or diversion would seem obviously smaller in a military facility than in an civilian facility--say at a university. However the risk-controlling factor at a given location is not ($d_{i,t}$) but the entire expression $P_{i,t}$ in Equation 2. The value of $A_{i,t}/M_b$ is much smaller than 1.0 for low power research reactors, while it can take values in excess of several hundred at military locations.

The assumption that diversion risk exposure per kilogram is not widely different, between the different materials (because of the offsetting effects of the factors controlling $P_{i,t}$) enables a semi-quantitative ordering of the rank of diversion risks for the categories shown in Table 1. Taking the historical value to date as the annual expected value $P_{tot} = .06$, the values in the right hand column are derived. On this scale, the conversion of overseas reactors to lower enrichment has appreciable overall value in reducing P_{tot}.

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*Nuclear Nonproliferation Act of 1978.

This leaves the spent fuel overseas as the dominant risk other than military material. On this scale the small domestic reactor exposure is about two orders of magnitude smaller than the residual risk from spent fuel overseas.

Reduction in the diversion risk exposure of U-235 in spent fuel overseas has at least equal value, per unit retired, as for small domestic research reactors. If $100 per gram retired from service domestically is a proper valuation, then instead of charging for the return of overseas U-235, the U.S. should be willing to pay for its return. If the values are equated, the U.S. should be willing to pay at least $0.6 Billion for comparable value in risk reduction.

References

(1) "Proposed Rule for Limiting the Use of High-Enriched Uranium (HEU) in Research and Test Reactors" NRC document Federal Register June 30, 1984.

(2) "Obstacles to U.S. Ability to Control and Track Weapons-Grade Uranium Supplied Abroad" U.S. General Accounting Office Report GAO/ID-82-21, August 1982.

TABLE 1. RANKING OF DIVERSION EXPOSURES

	CATEGORY	ESTIMATED VALUE $P_{i,t}$ PER YEAR
I.	WEAPONS MATERIALS AND FACILITIES	.05
II.	LARGE TEST REACTORS USING HEU ABROAD	
	A. Unirradiated fuel materials	.005 *
	B. Irradiated fuel	.005
III.	LARGE TEST REACTORS - DOMESTIC	.0005
IV.	SMALL RESEARCH REACTORS AT UNIVERSITIES	.00005

*Subject to gradual reduction 1985-1990 by displacement with low enriched uranium.

TABLE 2. Relative Cost vs. Risk Reduction Benefit of Current Commitments

Location	Type of Material At Risk	Number of Weapon-Equivalents Per Location	$ gram committed to reduce exposure
Domestic	Fuel for DOE Reactors	Several to Many	~0
Domestic	Fuel for non-DOE Reactors	0.1 to 0.2	> $100 *
Overseas	Future Fuel for Medium and high power Research & Test Reactors	Many	$20
Overseas	Spent Fuel Containing Highly Enriched U-235	Many dozens	< 0 **

*Based on ref. (1), if promulgated without changes.

**U.S. requires substantial payment to accept the return of such fuel.

DON FUQUA (Fla.), Chairman

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DAVID S. JEFFERY
Minority Staff Director

October 10, 1984

Carlton R. Stolber, Director
Office of Export and Import Control
U.S. Department of State
Washington, D.C. 20520

Dear Mr. Stolber:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

Don Fuqua
DON FUQUA, Chairman
Committee on Science
and Technology

Marilyn Lloyd
MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Mr. Stolber

1. Has there ever been either a successful or unsuccessful attempt to divert HEU fuel from a foreign research and test reactor?

2. Do you have any knowledge or information of any specific threats aimed at a foreign research and test reactor?

3. You noted that many nations are either developing LEU fuels or have reactor conversion studies underway. Is any other nation contemplating imposing a rule requiring conversions?

4. Does the Department of State have any assurances that if the NRC's proposed rule is implemented, other nations will impose similar requirements?

5. You noted that the actions of the NRC can be expected to have "some marginal effect on our future negotiations with foreign reactor operators." What weighting would you attach to the NRC action compared to the other 8 considerations listed at the end of your testimony?

6. Does the Department of State believe it would be necessary or helpful to the international nonproliferation efforts of the United stateds to convert domestic research and test reactors to LEU fuel?

7. Who should bear the costs of any domestic conversion to low-enriched fuel ordered to assist in our international nuclear nonproliferation efforts?

United States Department of State

Washington, D.C. 20520

NOV 18 1984

Dear Mr. Chairman:

In response to your letter of October 10, 1984 requesting additional information pursuant to the Department of State's testimony at the September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel, I am enclosing answers to your questions. We understand that these responses may be used to supplement the record of that hearing.

Please let me know if we can be of further assistance.

Sincerely,

Robert F. Turner
Acting Assistant Secretary
Legislative and Intergovernmental Affairs

Enclosure:
As stated.

The Honorable
Don Fuqua,
Chairman, Committee on Science
and Technology,
House of Representatives.

1. Q. Has there ever been either a successful or unsuccessful attempt to divert HEU fuel from a foreign research and test reactor?

A. To our knowledge, there has never been a successful or unsuccessful attempt to divert HEU from a foreign research and test reactor.

2. Q. Do you have any knowledge or information of any specfic threats aimed at foreign research and test reactor?

A. It should be kept in mind that most governments view terrorist threats as implicating their sovereign police powers; and we would expect much of that information to be treated confidentially. The only information we have had concerning specific threats aimed at a foreign research reactor involves the 1982 Israeli attack which destroyed the Osirak reactor in Iraq.

3. Q. You noted that many nations are either developing LEU fuels or have reactor conversion studies underway. Is any other nation contemplating imposing a rule requiring conversions?

A. We are not aware that any other nation is presently contemplating a rule requiring conversion of domestic research reactors to low enriched uranium. Conversion of foreign reactors will take place, as a result of participation by foreign reactor operators in the RERTR program, in which a schedule for conversion is developed in conjunction with development and testing of low enriched fuels and technical studies of conversion of individuals reactors. HEU exports are simultaneously being phased out in conjunction with the development of new LEU fuels. U.S. policy with regard to HEU exports provides a strong impetus to foreigners to move toward conversion.

4. Q. Does the Department of State have any assurances that if the NRC's proposed rule is implemented, other nations will impose similar requirements?

A. The Department of State has not sought or received any commitment from foreign governments that they will impose a similar requirement if NRC's proposed rule is implemented. As noted in the response to question 3 above, decisions by foreign governments to convert domestic reactors are being made in the context of their participation in the RERTR program and in light of U.S. policy on HEU exports.

5. Q. You noted that the actions of the NRC can be expected to have "some marginal effect on our future negotiations with foreign reactor operators." What weighting would you attach to the NRC action compared to the other 8 considerations listed at the end of your testimony?

A. We do not believe it is possible to assign precise weights or to rank the various factors which will influence foreign governments' attitudes toward conversion of their research reactors. However, we believe that some of the eight factors outlined in the State Department's testimony before the Subcommittee on Energy Research and Production are clearly more important in terms of shaping foreigners' attitudes than widescale implementation of the proposed NRC rule. Of the eight considerations outlined, clearly the following will be of great importance to foreign reactor operators in addition to the gradual phasing out of HEU exports from the U.S.:

-- the development of safe and reliable LEU fuels and their commercial availability;

-- the economics of conversion;

-- the availability of reprocessing services or back-end of the fuel cycle solutions for new fuels;

-- the regulatory steps which must be undertaken prior to conversion; and

-- the justifiable availability of HEU for operating reactors until the new fuels are ready.

6. Q. Does the Department of State believe it would be necessary or helpful to the international nonproliferation efforts of the United States to convert domestic research and test reactors to LEU fuel?

A. The Department of State believes that the adoption of some form of the proposed NRC rule can be expected to have "some marginal effect on our future negotiations with foreign reactor operators." We believe, if the NRC decides to go forward with a proposed rule, that the most sensible approach would be to study conversion of some reactors that require fuel reloads. Such an approach would make the domestic conversion program compatible with the RERTR program.

7. Q. Who should bear the costs of any domestic conversion to low-enriched fuel ordered to assist in our international nuclear non-proliferation efforts?

A. First, we take exception to the concept implied in the question that the proposed domestic conversion should be undertaken to assist in our non-proliferation efforts. If the NRC goes forward with the proposed rule, in our view, the federal government should bear virtually all of the costs for conversion of domestic reactors to LEU fuels. These costs include not only fuel costs, but licensing costs and technical studies for reactor conversion. University research reactors provide valuable research and teaching tools. We see no reason why hard pressed universities should be forced to bear these costs and, possibly, to be forced to shut down because of the burden of expenses related to research reactor conversion.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

October 10, 1984

James S. Kane, Deputy Director
Office of Energy Research
U.S. Department of Energy
Washington, D.C. 20585

Dear Dr. Kane:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

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MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Dr. Kane

1. What is the status of the university reactor report mandated by the FY 1985 Energy and Water Appropriation Bill? What is the anticipated scope of the report?

2. DOE currently accepts HEU fuel for storage or reprocessing. What is DOE's policy for LEU fuel?

3. You stated that DOE opposes conversion of reactors that have essentially a lifetime supply of fuel, and that you believe that theft or diversion of fuel from these small facilities is unattractive, and therefore extremely improbable. Does the DOE Assistant Secretary for Defense Programs concur with this position?

4. How many reactors would be converted if your preferred conversion scenario was followed? What would be the estimated cost and schedule?

5. If the NRC orders conversions, would DOE request funding to cover the costs of all these conversions, including fuel, analytical study and relicensing costs? Could we expect that DOE would continue to support the same number of university reactors?

6. Will any future DOE research reactors be designed for LEU fuel?

Department of Energy
Washington, D.C. 20585

October 29, 1984

Honorable Don Fuqua
Chairman
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

On September 25, 1984, James S. Kane, Deputy Director of the Office of Energy Research, appeared before the Subcommittee on Energy Research and Production to discuss the conversion of research and test reactors to low-enriched uranium (LEU) fuel.

Following that hearing, you submitted written questions for response to supplement the record. Enclosed are the answers to those questions, which also were sent directly to the Subcommittee Chairman Lloyd and Mr. Harlan L. Watson.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

J. Thomas Todd
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

POST-HEARING QUESTIONS AND ANSWERS

Relating to the

SEPTEMBER 25, 1984, HEARING

Before the

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

of the

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

WITNESS: JAMES S. KANE

Q. 1. What is the status of the university reactor report mandated by the FY 1985 Energy and Water Appropriation Bill? What is the anticipated scope of the report?

A. The House Committee on Appropriations in their report on the FY 1985 Energy and Water Appropriations Bill requested that the DOE report to the Committee by January 31, 1985, on the costs and related issues concerned with the conversion of university research reactors to LEU fuel. We are in the process of carrying out this study with the assistance of technical staff at the Argonne National Laboratory and at the Idaho National Engineering Laboratory. The scope of this study is as follows:

a. Evaluate and identify LEU fuel types for each class of university reactors now using HEU fuel;

b. Estimate LEU fuel fabrication and design specifications costs for the fuel;

c. Estimate the costs of converting each reactor affected by the proposed NRC rule to LEU fuel including safety analysis report preparation, facility and/or equipment changes and fuel shipping costs.

Staff at Argonne will shortly begin analyzing the various reactor types found at universities to determine the suitable LEU fuel for that particular facility. We anticipate completing all the tasks in time for submission of the overall report to the Committee by January 31, 1985.

Q. 2. DOE currently accepts HEU fuel for storage or reprocessing. What is DOE's policy for LEU fuel?

A. As noted, DOE currently accepts and reprocesses HEU fuels from U. S. and foreign research reactors. The reprocessing technology for the HEU plate-type fuels is well established and we are able to carry out the reprocessing in our current facilities.

Regarding the LEU fuels, we have carried out studies at the Savannah River Plant to determine whether LEU fuels can be reprocessed in existing DOE facilities. We are also looking at the costs associated with LEU recycle operations. We anticipate that these studies and the cost evaluations will be completed in the next several months, and at that time we will decide whether modifying our policies to include LEU fuel reprocessing is appropriate and cost effective.

Q. 3. You stated that DOE opposes conversion of reactors that have essentially a lifetime supply of fuel, and that you believe that theft or diversion of fuel from these small facilities is unattractive, and therefore extremely improbable. Does the DOE Assistant Secretary for Defense Programs concur with this position?

A. Our position on this point, which assumes suitable storage of excess fresh fuel at a DOE site, was developed in conjunction with staff in Defense Programs including assistance provided by technical experts at the Lawrence Livermore National Laboratory. The Assistant Secretary for Defense Programs does concur with this position.

Q. 4. How many reactors would be converted if your preferred conversion scenario was followed? What would be the estimated cost and schedule?

A. Six to ten university reactors would be converted to LEU fuel depending on the requirements included in the final NRC rule. We believe that the LEU fuel can be supplied at a cost of approximately $1.5 to $2.0M over a two to four year period.

Q. 5. If the NRC orders conversions, would DOE request funding to cover the costs of all these conversions, including fuel, analytical study and relicensing costs? Could we expect that DOE would continue to support the same number of university reactors?

A. DOE is responsible for providing the fuel for university nuclear research reactors and we would continue to request funding to cover the fuel conversion costs as part of our regular budget requests for the University Reactor Fuel Assistance Program. We do not currently plan to provide support for relicensing costs. However, as I pointed out in my testimony, we suggest that the NRC look closely at their licensing procedures to see what revisions are possible to lessen the impact (and costs) on those universities which might be faced with relicensing as a result of the final regulations. We note that several university representatives stated that a number of reactors may be closed down due to rising operational expenses and that a protracted relicensing process with its associated expense may affect the financial viability of additional reactors. Finally, we do plan to study the longer range needs for university nuclear reactors in terms of their use in both research and in manpower development. This study will assist us in determining whether or not all the remaining reactors currently supported will be needed in future years.

Q. 6. Will any future DOE research reactors be designed for LEU fuel?

A. There are no currently approved plans for constructing any new DOE research reactors.

DON FUQUA (Fla.), Chairman

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TOM LEWIS, FLA.

J. H. POORE
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

October 10, 1984

Armando Travelli, Manager
RERTR Program - Argonne National Lab.
9700 South Cass Avenue
Argonne, Illinois 60439

Dear Dr. Travelli:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

Don Fuqua

DON FUQUA, Chairman
Committee on Science
and Technology

Marilyn Lloyd

MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Dr. Travelli

1. How much have we invested in the RERTR program to date, and how much more will it cost to continue the program through 1989 to qualify the highest density fuel?

2. How much are other nations spending on the program?

3. On page 4 of your testimony, you noted that the operating characteristics of the Ford Nuclear Reactor at the University of Michigan are essentially unchanged with the LEU fuel. What do you mean by "essentially unchanged"? Hasn't there been a reduction in the reactor's neutron flux and a shift in its spectrum? Has this impacted any research projects at the reactor?

4. Has any of the LEU fuel been tested at extreme operating conditions, or only at steady-stated conditions? What about pulsing operations?

5. You noted that Savannah River Laboratory Laboratory tests indicate that several of the RERTR fuel types can be successfully reprocessed. Is the cost of reprocessing LEU fuel comparable to that of reprocessing HEU fuel?

6. Are the generic conversion and safety studies being carried out in the RERTR program directly applicable to our domestic research and test reactors? Do you agree with the ACRS that a new safety analysis report will be required for each conversion to low-enriched fuel?

7. You stated in your testimony that the new LEU fuels have been shown to offer considerable potential for economic advantages. What are these advantages?

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

October 31, 1984

The Honorable Don Fuqua, Chairman
Committee of Science and Technology

The Honorable Marilyn Lloyd, Chairman
Subcommittee on Energy Research and Production

U.S. House of Representatives
Committee on Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Fuqua and Ms. Lloyd:

Thank you again for giving me the opportunity to testify at the hearing which your subcommittees held on September 25, 1984 on the Conversion of Research Reactors to Low-Enriched Uranium (LEU) Fuel.

I am enclosing my responses to the questions which I recently received from your office to supplement the record of the hearing.

Please let me know if I can assist in any other way.

Sincerely yours,

Armando Travelli
RERTR Program Manager

AT:cs

Enclosure

U.S. Department of Energy   The University of Chicago

Additional Questions for Dr. Travelli

1. How much have we invested in the RERTR program to date, and how much more will it cost to continue the program through 1989 to qualify the highest density fuel?

The RERTR program has spent approximately $24 million to date, in current dollars. A projection of future program funding requirements has been submitted to the Department of Energy (DOE) and is under review. I understand that DOE will provide the results of this review in their response to the Subcommittees.

2. How much are other nations spending on the program?

A complete and precise answer to this question would require information which is not currently available to the RERTR program. Foreign technical contributions to the goals of the RERTR program have been very significant, but the RERTR program is seldom apprised of their cost.

The only foreign program whose total costs are known to us is the AF program[1] *of the Federal Republic of Germany (DM 40.0 million, or $13.3 million at the current exchange rate). I estimate that the total combined costs incurred by programs in other countries amount to at least twice as much as those of the AF program alone. Program costs in Japan, France and Canada are estimated to have been particularly high, but significant contributions have come from Argentina, Austria, Denmark, the Netherlands, Sweden, Switzerland, and the United Kingdom.*

In total, this rough estimate corresponds to other nations having spent at least $40 million on programs related to the use of reduced enrichment fuels in research and test reactors.

3. On page 4 of your testimony, you noted that the operating characteristics of the Ford Nuclear Reactor at the University of Michigan are essentially unchanged with the LEU fuel. What do you mean by "essentially unchanged?" Hasn't there been a reduction in the reactor's neutron flux and a shift in its spectrum? Has this impacted any research projects at the reactor?

The operating characteristics of the Ford Nuclear Reactor (FNR) have changed so little with the conversion to LEU that the changes are difficult to measure. In a recent presentation[2] *to the 1984 International RERTR Meeting, Mr. R. Robert Burn, Manager of the Ford Nuclear Reactor, systematically addressed how the parameters most important to a reactor operator have changed with the conversion. His concluding words were:*

"From an operational point of view, we have literally seen no significant effects of converting to LEU and in fact it is questionable whether there really are any differences. The things that we have observed are that the thermal flux within the core has decreased slightly but the thermal leakage fluxes have increased, which is really better for experimenters. Rod worth, temperature coefficient, voids (coefficients), *and power defect have changed almost imperceptibly."*

These results are consistent with RERTR program calculations. The increase in thermal leakage fluxes is probably due to the slightly smaller size of the LEU core. The results from the Ford Nuclear Reactor confirm the validity of RERTR evaluations, but should not be interpreted to mean that the same effects would be seen in all converted research reactors.

4. Has any of the LEU fuel been tested at extreme operating conditions, or only at steady-state conditions? What about pulsing operations?

Some tests corresponding to extreme operating conditions and to hypothetical accident conditions have been performed on the new ~~LEU~~ fuels. These tests were chosen to follow closely those used in the past to qualify HEU fuels.

Pulsing tests have been performed on the new LEU TRIGA fuels designed for pulsing. TRIGA reactors are the only reactors considered by the RERTR program that are designed for pulsing operations.

The main tests which have been performed are described below:

(a) Miniplates, rods and full-sized elements have been irradiated to much higher burnups than required by normal operating conditions.

(b) After irradiation, "blister tests" have been performed on miniplates and full-sized elements of all LEU plate-type fuels. In these tests, the fuel temperature was gradually raised to near the melting point of the cladding, while monitoring for any visible evidence of damage.

(c) Fission product release tests have been performed on LEU miniplates that had been irradiated to very high burnups. The plates were gradually heated beyond the melting point of aluminum, while the release of fission products was monitored. Fission product release tests of LEU $UZrH_x$ *(TRIGA) pins have also been performed by GA Technologies, Inc.*

(d) Pulsing tests on LEU $UZrH_x$ *(TRIGA) pins designed for pulsing have been performed by GA Technologies, Inc. In these tests, essentially fresh pins were subjected to 2000 full power cycles with 16 transient pulses to verify their suitability for pulsing operations.*

These tests related to extreme operating conditions and to hypothetical accident conditions were performed, in addition to tests related to normal operating conditions, with the intent of providing the licensing authorities with adequate data to assess the safety aspects of the new fuels. Personnel from licensing authorities of the main countries involved with the program have been periodically informed of the type, scope, and results of the tests.

5. You noted that Savannah River Laboratory tests indicate that several of the RERTR fuel types can be successfully reprocessed. Is the cost of reprocessing LEU fuel comparable to that of reprocessing HEU fuel?

The cost of reprocessing LEU fuel is the subject of an ongoing study by the Department of Energy. I understand that the study will be concluded by the end of calendar year 1984.

6. Are the generic conversion and safety studies being carried out in the RERTR program directly applicable to our domestic research and test reactors? Do you agree with the ACRS that a new safety analysis report will be required for each conversion to low-enriched fuel?

The generic studies performed by the RERTR program provide general qualitative answers related to the performance, safety, and economics of various reactor types. Therefore, they are equally applicable to foreign and domestic research and test reactors.

I disagree with the statement that an entirely new safety analysis report will be required for each conversion to LEU. Only those portions of the safety analysis report which are related to changing the fuel from HEU to LEU need to be considered, and some of these portions can be addressed in a generic manner. For example, the qualification of the fuels can be addressed generically for most reactors.

Research reactors can be categorized into several groups. Two examples are the Argonaut and TRIGA reactors. Reactors in the same group are very similar, although each may have some differentiating features. Many of the remaining safety issues related to the fuel change could be addressed generically within each group. For instance, the relevant data could be incorporated into existing safety documents by reference to generic documents. We understand that this is already an established practice of the Nuclear Regulatory Commission.

7. You stated in your testimony that the new LEU fuels have been shown to offer considerable potential for economic advantages. What are these advantages?

Many of the research and test reactors now in operation with HEU fuel use elements which contain relatively small amounts of ^{235}U. Because of this, the reactors must change their fuel frequently and incur high costs for fuel fabrication, shipping, and reprocessing. The economic operation of these facilities could be significantly improved by using fuel elements with greater ^{235}U content because these elements would last longer.

The ^{235}U content can be increased by using either the old HEU fuels or the new LEU fuels. In this context, there no intrinsic economic advantage to using LEU, but only a few reactors have taken advantage of the HEU fuel densities that have been available for the past 15 years. The conversion process to LEU offers an opportunity to increase the fissile loadings of the elements and to improve operating economy.

The potential advantages would be greatest for reactors which currently have the lowest ^{235}U loadings, and would gradually decrease as the current loadings increase.[3]

An additional economic advantage could be achieved by standardizing the LEU fuel plates to be used in research and test reactors. Fabrication of fuel elements containing standard plates is estimated to cost at least 15% less than fabrication of elements containing custom-made plates.

References:

1. G. Thamm (KFA, FRG), "Five Years of German AF - Programme: Review and Outlook," Proceedings from the 1984 International Meeting on Reduced Enrichment for Research and Test Reactors, Argonne National Laboratory, October 15-18, 1984 (to be published).

2. R. R. Burn (University of Michigan, U.S.), "Operational Impacts of LEU Core Conversion at the Ford Nuclear Reactor," same as Ref. 1.

3. J. E. Matos (ANL, U.S.), "A Fuel Cycle Cost Study with HEU and LEU Fuels," same as Ref. 1.

Department of Energy
Washington, D.C. 20585

November 6, 1984

Honorable Don Fuqua
Chairman, Committee on Science
and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

On September 25, 1984, James S. Kane, Deputy Director of the Office of Energy Research, appeared before your Subcommittee to discuss the conversion of research and test reactors to low-encriched uranium (LEU) fuel. Dr. Kane was accompanied by Armando Travelli, Manager, RERTR Program, Argonne National Laboratory.

Following the above hearing, you submitted written questions to Mr. Travelli for his response to supplement the record. Since the Department of Energy (DOE) is responsible for technical administration of the Reduced Enrichment for Research and Test Reactors (RERTR) Program with day-to-day technical management and program coordination performed for DOE by Argonne National Laboratory, questions 1 and 5 have been answered by DOE and are enclosed. Dr. Harlan Watson of the Committee staff agreed this arrangement would be acceptable. Copies of the enclosed answers also have been sent directly to the Subcommittee Chairman Lloyd and the staff.

The remainder of the answers will be sent to you directly by Mr. Travelli.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

Q. 1. How much have we invested in the RERTR program to date, and how much more will it cost to continue the program through 1989 to qualify the highest density fuel?

A. Funding provided to the program through FY 1984 amounts to approximately $24M. To bring the technical efforts to completion through qualification of the high density fuel system expected in FY 1989 will require approximately that much again ($24M more for a total of $48M).

Q. 5. You noted that Savannah River Laboratory tests indicate that several of the RERTR fuel types can be successfully reprocessed. Is the cost of reprocessing LEU fuel comparable to that of reprocessing HEU fuel?

A. At present, DOE is investigating the anticipated costs associated with LEU recycle operations. We anticipate these evaluations will be completed in the next several months and will establish the relative cost of reprocessing LEU and HEU fuel.

DON FUQUA (Fla.), Chairman

ROBERT A. ROE, N.J.
GEORGE E. BROWN, JR., CALIF.
JAMES H. SCHEUER, N.Y.
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J. H. POORE
Executive Director
ROBERT C. KETCHAM
General Counsel
DAVID S. JEFFERY
Minority Staff Director

October 10, 1984

Robert S. Carter, Chief
Reactor Radiation Division
National Bureau of Standards
Washington, D.C. 20234

Dear Dr. Carter:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

DON FUQUA, Chairman
Committee on Science
and Technology

MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Dr. Carter

1. Suppose the NRC decides to order the conversion of at least some research and test reactors. How would you recommend that this proceed in the least painful manner?

2. What actions would you recommend this Committee take with regard to this matter?

3. How does the performance of the NBS reactor compare with that of the MIT and University of Missouri reactors?

4. What types of research are carried out at the NBS reactor?

5. Does the NBS reactor produce any radioisotopes?

6. The conversion cost for the NBS reactor is estimated to be $2.0 million and the increased operating cost is estimated to be about $600,000. Do these figures assume the use of the higher density fuels which should be available in the 1989 time frame?

7. Will it eventually be possible to convert the NBS reactor to LEU fuel provided that the higher density fuels are qualified?

8. You noted that conversion to LEU fuel would decrease the beam intensities by 10 to 15 percent. Could you compensate for this by operating at a 10 to 15 percent higher power level?

9. You noted that conversion to LEU fuel would decrease the quality of the research beams by about 25 percent. What do you mean by the term "beam quality" and what does this mean in terms of the ability to perform research?

10. In your testimony before the NRC this past December, you stated that the Europeans had "recently built new research reactors." How many such new research reactors have recently been completed, are under construction, or planned? Will they all use HEU fuel?

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
~~Washington, D.C. 20234~~
Gaithersburg, MD 20899
(Mailing Address Change Only)

NOV 14 1984

Honorable Don Fuqua
Chairman, Committee on Science and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman

Thank you for the opportunity to supplement the record of the hearing held September 25, 1984. Enclosed are the answers to the questions attached to your letter of October 10, 1984.

I appreciated the opportunity to present testimony on the matter.

Sincerely,

Robert S. Carter

Robert S. Carter
Chief, Reactor Radiation Division

Enclosure

Questions and Answers for the Record
Robert S. Carter, Chief, Reactor Radiation Division

1. Question: Suppose the NRC decides to order the conversion of at least some research and test reactors. How would you recommend that this proceed in the least painful manner?

   Answer: The most important step would be to let those reactors which are required to convert to low-enriched uranium (LEU) fuel to use up all their existing high-enriched uranium (HEU) fuel and convert to LEU only when they need new fuel. This is consistent with the U. S. position with regard to overseas research reactors and would permit an orderly phase-in of the new LEU fuels at significantly lower cost than immediate conversion. It should be noted that many small research reactors might have to shut down because the costs of conversion would far exceed their limited budgets. And, finally, steps should be taken to mitigate any licensing problems that might arise. For example, the NRC rule might clearly state that HEU may continue to be obtained and used until final approval for LEU use is obtained. This would avoid the "catch 22" situation in which new fuel is required to continue operation during a protracted licensing procedure, but LEU is not yet approved and the use of new HEU fuel is forbidden by the NRC rule.

2. Question: What actions would you recommend this Committee take with regard to this matter?

   Answer: Based on the testimony presented, NBS respectfully suggests that the committee find that the mandatory conversion of research and test reactors to LEU fuel is not in the best interest of the government or the general public and that the proposed rule not be implemented.

3. Question: How does the performance of the NBS reactor compare with that of the MIT and University of Missouri reactors?

   Answer: The NBS, Missouri, and MIT reactors are all high-performance reactors operating at 20, 10, and 5 megawatts, respectively. Both NBS and Missouri have extensive and comparable programs in activation analysis and isotope production with somewhat less activity at MIT.

   The NBS reactor (NBSR) has several features including the use of heavy water as a moderator, large diameter beam holes, and a split core configuration to maximize the quality of the neutron beams from the reactor. These features combined with the higher power of the NBSR result in higher quality and higher intensity beams than are available at Missouri or MIT. The NBSR also has more beams than either Missouri or MIT and supports more major facilities (25) than any other research reactor in the U. S. Ten of these facilities support an extensive, world-class program in materials science. Six of the ten materials science facilities are as good or better than any in the U. S. including the non-licensed DOE reactors. Furthermore, the NBSR is the only reactor in the U. S. in which a large cold neutron source can be installed to serve a full compliment of cold neutron research instruments to make the U. S. competitive with the Europeans in this important area of research.

Although neither Missouri nor MIT have the number and quality of neutron beams to mount as extensive a program in materials science as NBS, they have fine facilities in other areas including some world-class facilities in the areas of neutron optics, neutron interferometry, gamma-ray spectroscopy, and neutron doping of silicon.

4. Question: What types of research are carried out at the NBS reactor?

Answer: The major types of research carried out at the NBSR are materials science, chemistry, trace analysis, neutron standards and dosimetry, and nondestructive evaluation. About 250 scientists and engineers from 16 divisions and offices of NBS, 18 other agencies, and 35 university and industrial laboratories use the NBSR in these areas of research.

The NBSR is a national center for the application of neutron methods to the characterization of materials. Examples of some of the materials research are: the study of the structure and microscopic behavior of polymers, catalysis, biological materials, ceramics, and rapidly solidified metals, and the probing of critical properties of high technology magnetic materials, semiconductors and superconductors.

Neutron activation analysis is used to measure trace elements in foods, drugs, environmental samples, and Standard Reference Materials (SRM). An SRM is a material sample whose composition has been carefully determined and certified by NBS to be used as a measurement reference by other laboratories.

The neutron standards program uses well-characterized neutron fields that have been established in the NBSR to calibrate and develop instruments and methods to measure neutron intensities and spectra in power reactors. The dosimetry program uses special filtered neutron beams to calibrate and develop devices for measuring personnel neutron radiation exposures.

Neutron methods are used by NBS in a variety of ways to examine materials and objects nondestructively. They are used to examine materials for minute cracks and the residual stresses left in materials after processing. And they are used to make radiographs of critical components and of works of art. Rare paintings have been radiographed to study them in more detail than is available by other means and, in some cases, to check their authenticity.

5. Question: Does the NBS reactor produce any radioisotopes?

Answer: The NBSR does not generate radioisotopes that are commercially available. It does make some radioisotopes that are not generally available for special scientific or medical purposes. The major example of this is flourine-18. It has a two-hour half life and is used in medical research by the National Institutes of Health.

6. Question: The conversion cost for the NBS reactor is estimated to be $2.0 million and the increased operating cost is estimated to be about $600,000. Do these figures assume the use of the higher density fuels which should be available in the 1989 time frame?

Answer: The $2.0 million dollar figure is the estimate of the cost of scrapping the present NBS inventory of fuel elements. As such, it includes the cost of fabricating the existing fuel elements and the cost of shipping and reprocessing them to recover the U-235. The increase in operating cost assumes the use of the higher density silicide fuels that may be available in the 1989 time frame. Based on the information currently available, both the cost of fabrication and reprocessing of silicide fuels would be higher than the U_3O_8 fuels we use now. The additional U-238 in the fuel would adversely affect the fuel utilization. These factors combine to increase the annual fuel cycle cost by about 40 percent resulting in the $600,000 estimate.

7. Question: Will it eventually be possible to convert the NBS reactor to LEU fuel provided that the higher density fuels are qualified?

Answer: The higher density silicide fuels, if successfully developed, could be used in the NBSR. But it would result in a decrease in neutron flux by 10 to 15 percent and a reduction in beam quality (see the answer to question 9) by as much as 25 percent. Furthermore, the testing would have to include much more than demonstrating successful operation under normal operating conditions. It would have to demonstrate that the new fuel would behave as well under accident conditions as the present proven fuel does.

8. Question: You noted that conversion to LEU fuel would decrease the beam intensities by 10 to 15 percent. Could you compensate for this by operating at a 10 to 15 percent higher power level?

Answer: No, the NBSR is already licensed to operate at its maximum design power. Its power could not be increased without major modifications of the cooling system. This would require the investment of several million dollars, a prolonged reactor shutdown, and a major relicensing procedure. In general, all high-performance reactors are operating at their maximum design power.

9. Question: You noted that conversion to LEU fuel would decrease the quality of the research beams by about 25 percent. What do you mean by the term "beam quality" and what does this mean in terms of the ability to perform research?

Answer: The quality of a thermal neutron beam is determined by the intensity of the thermal neutrons, as compared to the intensity of unwanted radiation such as fast neutrons and gamma rays. The use of LEU fuel both decreases the thermal neutron flux and increases the background radiation. Even if the use of LEU fuel left the background unchanged, many frontier-type experiments would be affected by much more than 10-15 percent loss in thermal neutrons. These experiments are so difficult that the background is often a large factor of the total counting rate. For example, if the background were one-half the total counting rate, an experiment would have to run 25 percent longer to compensate for the 10-15 percent decrease in thermal neutron flux caused by the use of LEU. Such an increase in time to perform an experiment would mean that many frontier experiments that could otherwise be carried out at the NBSR could no longer be attempted.

10. Question: In your testimony before the NRC this past December, you stated that the Europeans had "recently built new research reactors." How many such new research reactors have recently been completed, are under construction, or planned? Will they all use HEU fuel?

Answer: The Orphee reactor in France is the most recently completed entirely new reactor. It was completed in 1980 and useful experiments were initiated in 1981. It operates at 14 MW and is equipped with extensive experimental facilities including a hot source, two cold sources, and a neutron guide hall. It has a very small core that uses HEU fuel to provide maximum thermal neutron flux for reactor power. Two other reactors in Europe are in the process of major upgrading including complete replacement of the core and reflector structure. One, in Berlin, is being upgraded from 4 to 20 MW and the other, in Munich, is being upgraded from 5 to 10 MW. Both are designed to use higher enrichment fuels. The USSR has an advanced research reactor under construction at Leningrad. It will operate at 100 MW and probably use HEU fuel. And the Japanese are planning a new, 30 MW reactor which will use HEU fuel, if available. All of these reactors have major cold neutron sources and associated neutron guides and experimental facilities.

DON FUQUA (Fla.), Chairman

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Minority Staff Director

October 10, 1984

Mr. James J. McGovern
Union Carbide Corporation
Medical Products Division
Tuxedo, New York 10987

Dear Mr. McGovern:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

DON FUQUA, Chairman
Committee on Science
and Technology

MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Mr. McGovern

1. Suppose the NRC decides to order the conversion of at least some research and test reactors. How would you recommend that this proceed in the least painful manner?

2. What actions would you recommend this Committee take with regard to this matter?

3. If Union Carbide went out of the radioisotope business, could any other reactors operated by, say, DOE fill the gap, or would we have to depend on foreign suppliers?

4. What level of revenues does Union Carbide receive from the sale of radioisotopes? How many jobs are attributable to this enterprise?

5. Do your competitors all use HEU fuel? Do any of them plan to convert to LEU fuel?

6. Do your increased operating cost estimates presume the use of LEU targets? What would be the impact on your operations and to the cost of isotopes if you were required to use LEU targets?

UNION CARBIDE

UNION CARBIDE CORPORATION P. O. BOX 324, TUXEDO, NEW YORK 10987
MEDICAL PRODUCTS DIVISION TELEPHONE NUMBER: (914) 351-2131

November 7, 1984

U. S. House of Representatives
Committee on Science & Technology
Suite 2321 Rayburn House Office Bldg.
Washington, DC 20515

Attention: Honorable Don Fuqua, Chairman Committee on Science and Technology

Attention: Honorable Marilyn Lloyd, Chairman Subcommittee on Energy Research and Production

Gentlemen:

Your letter of October 10, 1984 requested additional information to supplement our testimony that was given at your Committee hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel. This supplementary information is presented below in the same order as it was requested.

1) An NRC mandate to require the conversion of at least some research and test reactors would only be a symbolic gesture that would have little impact on reducing the risk of diverting HEU for unauthorized purposes. Accordingly, we recommend that those reactors be chosen which will not be adversely effected. Since the Ford Nuclear Reactor has already gone through such a conversion, perhaps there are other reactors of the same design with operating requirements that will not be effected significantly. Perhaps a generic safety evaluation report could be developed from the basic data gathered from the Ford Reactor conversion which could be applied to the other reactors as a "standard plant design" relicensing. We have been told that some university reactors are having a difficult time with funding. If the conversion to LEU were completely subsidized, perhaps some would welcome this conversion to overcome short-term fiscal difficulties, especially if the conversion didn't interfere significantly with current programs.

2) Our comments to the NRC regarding the proposed rule to require the conversion of research reactors to LEU are enclosed. We included recommendations for alternative effective measures which could be taken that would reduce the risk of diversion even lower than the low level that currently exists. One of these alternatives is to utilize the current state-of-the-art higher density fuel for producing high density HEU fuel with burnable poison to prolong the fuel life. This would reduce the amount of fuel that would be required in transit as well as in storage at the facilities. The technology to accomplish this is already at hand from the RERTR program. We recommend that

2) (Continued)

the Committee look at this option through the RERTR program as a possible solution to this problem that, hopefully, all reactors could implement. This alternative would utilize the investment in the RERTR program to reduce the risk of diversion while increasing productivity in all reactor facilities.

3) If Union Carbide went out of the radioisotope business it would be possible for other, DOE operated reactors, to fill the gap; but this could not be done immediately. A substantial lead-time would be required to install irradiation and radiochemical processing facilities to meet the production volume requirements. This became very evident when the General Electric Test Reactor (GETR) ceased operation in 1977. Fortunately the UCNR had sufficient excess capacity to fill a major part of the gap left by the GETR. The demand that we were not able to satisfy went to foreign suppliers. (Some buyers would have gone overseas anyway for commercial reasons.) Our guess is that a DOE facility could not respond quickly enough to fill a future precipitous gap and therefore most of the demand would go to foreign sources. If current foreign suppliers could not fill the shortfall completely, there would be a shortage of supply for some indefinite period.

The idea that DOE is standing by to take over for private enterprise is contrary to the basic premise of the Atomic Energy Act of 1954, the cornerstone of the "Atoms for Peace" program and also the impetus for commercial entry into the field of nuclear technology. The idea that, 30 years after the Act, we are discussing the possibility that regulations under the Act may become a major impediment to private enterprise is quite a paradox.

4) The exact gross sales that are generated from the sales of radioisotopes is considered by us to be business-confidential information. We can say that the sale of bulk radioisotopes is in the order-of-magnitude of 10's of millions of dollars. There are approximately 100 people directly involved in the production and distribution of bulk radioisotopes.

It should be mentioned that the extension of the bulk radioisotope business into the manufacture of pharmaceuticals and research chemicals is an industry that employs thousands of people and generates a revenue of hundreds of millions of dollars.

5) The competitors of Union Carbide that are in the bulk radioisotope business use high power test reactors that are operated by either government agencies or consortia. All these reactors use highly enriched uranium fuel.

5) (Continued)

We don't know of their plans for converting to LEU. However, we do know that they are reluctant to do so. The USA is their only current source of HEU and they feel uneasy about a continued supply. An individual from the foreign test reactor community has made statements about seeking an alternate supply.

6) The estimated cost increases are based only on the change to LEU fuel. Our current technology for radioisotope production does not include the use of LEU. Notwithstanding that fact we have considered the practicality of using LEU targets in the UCNR 5MW reactor. We concluded that it would be impractical to sustain the current volume of production and it would be an unviable situation financially. We could not continue in the business.

Thank you again for your interest in the details of this issue. We hope that the perceived problem posed by the use of HEU in research and test reactors will be weighed against the magnitude of the past and planned future efforts of the presently conceived RERTR program. We believe that a less expensive and perhaps more immediate solution is available per our comments on the NRC proposed rule.

Very truly yours,

JJ McGovern

J. J. McGovern
Business Manager Radiochemicals

JJMcG:aln

UNION CARBIDE

UNION CARBIDE CORPORATION P O BOX 324, TUXEDO, NEW YORK 10987
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October 26, 1984

U. S. Nuclear Regulatory Commission
Secretary of the Commission
Washington, DC 20555

Attn: Docketing and Service Branch

Subj: Comment on Proposed Rule

Gentlemen:

The Nuclear Regulatory Commission published for comment a proposed rule which will limit the use of highly enriched uranium (HEU) in domestic Research and Test Reactors in the July 6, 1984 Federal Register Vol. 49, No. 133, pp. 27769 thru 27772. The Union Carbide Research Reactor (UCNR) located at the Sterling Forest Laboratory, in Tuxedo, New York, uses HEU fuel and the conversion of this fuel to low enriched uranium (LEU) could be required by this proposed rule.

The operating characteristics of a reactor that is fueled with LEU will be different from those of an HEU fueled reactor and, since all of the existing UCNR operating parameters are based on an HEU core and since all of the products and services currently provided by this reactor were developed in an HEU core and since the financial base of operation has been established from experience with an HEU core, the conversion of the UCNR from HEU to LEU fuel will have a significant impact on all aspects of the operation of the facility. We expect the same situation exists at most other operating facilities that use HEU fuel. Therefore we offer the following comments concerning this proposed rule.

The NRC policy to limit the quantity of HEU in use is intended to reduce the risk of theft or diversion of HEU for unauthorized purposes. The NRC states that "HEU in appropriate form and quantity can be used to make an explosive device". The proposed rule to require research reactors to convert to LEU fuel is intended to implement that policy.
A recent risk assessment[1] which examines the relative risk of having research reactor HEU fuel used for making an explosive device reveals that the research reactor community presents the least exposure for diversion of HEU. Futhermore it points out that the quantity and form of HEU that is normally present in a research reactor facility is insufficient to manufacture a basic device (crude bomb) even if the equivalent resources of a U. S. National Laboratory were employed in its manufacture. This situation was corroborated by testimony of other knowledgeable people in the hearings on this subject that were conducted by the NRC Commissioners, the ACRS and the House Committee on Science and Technology. Given this information it can be concluded that the proposed rule will have little or no impact in carrying out the stated policy.

Higher risks for the diversion of HEU exist outside of the research reactor community. These have been identified recently during the many public discussions and hearings that were precipitated by this proposed rule. It appears imprudent and inconsistent to apply this rule only to the small NRC licensed, Research Reactor community. It is also apparent that a large amount of HEU is in storage in the form of irradiated fuel, most of which is overseas, which poses a greater risk for diversion than the HEU that is in immediate use. It seems that a more prudent expenditure of resources would be to return this HEU material that is in storage to the U.S. and recycle it into the system that is more secure. The cost of removing this high risk will be orders-of-magnitude less than the approximately $30 million already spent on the RERTR program.

[1] Testimony of E. Zebrosky before the ACRS hearing on HEU/LEU conversion 06/12/84.

We note that the NRC hopes to encourage the conversion of foreign reactors as a result of the proposed rule. Foreign operators and governments are inclined to view the U.S. as one entity and therefore may not percieve this rule as encouragement to follow because most of the HEU in domestic use is in facilities operated by DOE and it will be exempt from the requirements of the proposed rule.

The above general comments notwithstanding, several technical issues remain unresolved which will have an impact on reactor core characteristics, operating parameters, license limits and costs. These issues conflict with the basic premise of the RERTR LEU conversion program which is to avoid "significant changes to existing facilities or significant decrease in performance characteristics of the reactors". It is important to consider the purpose or raison d'etre of a reactor as much as whether it is technically feasible and safe to operate with LEU fuel when assessing the impact of conversion.

The low density, high enriched fuels currently in use have been proven to be reliable over more than 30 years of normal operation in numerous reactors and under accident conditions as demonstrated in the SPERT and BORAX tests. Normal performance of the lower density LEU fuels has been modeled in computer codes and verified but performance under accident conditions has not been verified with experimental data. In the areas of safety and reliability the presently used aluminide and oxide HEU fuels are excellent. The low density HEU fuel matrix provides interstitial space for the fission products without resulting in fuel plate swelling when yielding greater than 50% burnup in service. The LEU fuels accommodate the low enrichment via much denser fuel loading. This denser matrix has much less space for fission product volume increases and therefore it could be more prone to swelling. The denser uranium fuels will have a different thermal conductivity. These phenomena could alter the retention of the fission product source term and they should be fully understood before wholesale conversion to LEU is mandated.

The neutron flux energy spectrum in LEU cores may alter control rod worths, the effective delayed neutron fraction and other important characteristics, all of which could change operating margins or require revision of operating limits. The percieved benefit of the LEU conversion issue is to reduce the risks to the public due to HEU diversion. Are we trading risks here? The perceived diversion risk is supposed to be reduced with LEU but the price is the substitution of a relatively untested fuel for a proven, accident tested fuel.

The IAEA LEU Core Conversion Guidebook (IAEA-TECDOC-233 App. F-1 MTR Benchmark Calculations) predicts a hardened neutron energy spectrum and an approximate 10% reduction in the thermal neutron flux after LEU conversion. These predictions were generally confirmed in the Ford Reactor conversion to LEU. Our reactor is basically a thermal neutron source for producing radioisotopes and performing nuclear irradiation services. A 10% reduction in thermal neutron flux will result in a 10% reduction in productivity. The "harder" flux will also reduce the quality of our major service irradiation work, neutron transmutation doping of electronic grade silicon. These consequences of conversion to LEU cause a "significant decrease in performance" of the UCNR.

The major radioisotope products that are manufactured in the Sterling Forest Facility are separated from the fission products of U-235. The hardened flux spectrum, manifested by the reduction of thermal flux and the increase in epithermal flux, will result in an increase of Pu-239 (U-238, n-γ reaction) in our radioisotope production waste. If the Pu-239 content of the waste were deemed to exceed 10 CFR 61 limits there is no disposal method for such waste currently available. If Union Carbide had no approved method or disposal site for this waste we could not continue operations.

Over the last five years the UCNR has made progress in increasing operating efficiency by improved fuel management while using HEU fuel. The useful life of each fuel element has been extended by increasing the burnup per element. We also have been considering higher U-235 loading per fuel element and the addition of burnable poisons to further increase fuel life. As the high density uranium-aluminum technology proceeded we saw more opportunities, utilizing HEU, to reduce our reactor operating costs and increase our overall productivity. These opportunties disappear if the high density technology is taken up by LEU conversions.

Conversion to LEU will have other negative economic consequences which will be realized more immediately. Even if the out-of-pocket conversion cost is subsidized by the Government, we can foresee significant indeterminate costs which will be required for amending license conditions. Changed reactor operating characteristics will require safety analyses, technical specification changes, revised operating procedures and revised training and requalification programs. License amendment proceedings are often open-ended, unpredictable affairs. This cost will be compounded because the technical staff involvement in these licensing issues will be a distraction from the usual, more productive work.

After a conversion were accomplished, we anticipate increased reactor operating costs due to reduced thermal neutron flux levels, higher fuel fabrication costs and increased fuel reprocessing costs. This is particularly important at our Sterling Forest Reactor because of its function in radioisotope production. We have estimated that the overall cost of isotopes production could increase approximately 20% after LEU fuel were substituted for HEU fuel. The details of this anticipated cost increase were provided to the NRC in previous correspondence during hearings on this rule.

There exists, in addition to the above mentioned economic impact, an impending major risk for incurring legal costs if the LEU conversion rule will allow opportunities for public hearings under 10 CFR 51. There is little incentive to carry out long and costly litigation in the hearing process particularly when an intervenor's ultimate objective is to delay operation indefinitely. The university reactor community has stated that many reactors would cease operation in such circumstances. The long-term societal cost of this eventuality is real considering that a large and increasing source of energy in this country is from nuclear energy. These university research reactors are vital to maintain and improve the technology that will be needed in this industry.

Although we agree with the objective of the proposed rule we believe that it will do little to accomplish it. There appear to be more effective and less costly steps that can be taken immediately to reduce the risk of diversion of HEU from research reactor facilities. We propose the following actions to achieve this purpose:

(1) Limit the amount of fuel at any reactor site to a bare minimum to sustain reliable operation. It is especially desirable to eliminate as much as possible the amount of fresh fuel by dispensing it from a central, secure respository as it is needed at each facility.

(2) Reduce the domestic and international traffic of HEU through the use of fuels that have longer useful life. This could be accomplished through higher density HEU loadings containing burnable poisions. The RERTR program has made this technology accessable now without going to extremely high densities.

(3) Require that irradiated spent HEU fuels be returned to the U.S. within some minimum time that is dictated by safe transport and cask availablity.

This proposed rule is going to place a burden on the research and test reactor community that is disproportionate to the relatively low risk that these facilities present for diversion of HEU for the ultimate purpose of manufacturing an explosive device. We believe that it should not be implemented.

cc: J. Franzen
D. Gallaher
A. Shirk
R. Strack
W. Rudley
W. Ruzicka

Very truly yours,

James J. McGovern
Business Manager
Radiochemicals

JJMcG: is

DON FUQUA (Fla.), Chairman

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General Counsel
DAVID S. JEFFERY
Minority Staff Director

October 10, 1984

Dr. A. Francis DiMeglio
Nat'l Org. of Test, Res. & Training Reactors
Rhode Island Nuclear Science Center
Narragansett, RI 02882

Dear Dr. DiMeglio:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

Marilyn Lloyd

DON FUQUA, Chairman
Committee on Science
and Technology

MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Dr. DiMeglio

1. Suppose the NRC decides to order the conversion of at least some research and test reactors. How would you recommend that this proceed in the least painful manner?

2. What actions would you recommend this Committee take with regard to this matter?

3. Which non-power reactors does the National Organization of Test, Research and Training Reactors (TRTR) represent? Does the TRTR membership include any of the private or government reactors?

4. You stated that "TRTR believes that the risks of significant diversion can be made acceptable by means of appropriate security and by engineering fixes such as long-live cores." Does this mean that TRTR believes that the current level of risk is unacceptable at any or all of its member facilities?

5. What is the estimated cost of these security and engineering fixes?

6. You noted that "forced conversion will most certainly result in shutting down several facilities." How many do you estimate will be shut down even if the federal government picks up the conversion costs?

7. What is TRTR's estimate of the conversion costs of your members' reactors?

8. How much would it cost to decommission a typical university reactor?

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RHODE ISLAND ATOMIC ENERGY COMMISSION
Nuclear Science Center
South Ferry Road
Narragansett, R.I. 02882-1197

October 30, 1984

Subcommittee on Energy Research
and Production
Subcommittee on Energy Development
and Applications
Room B 374
Rayburn House Office Building
Washington, DC 20515

Attention: Dr. Harlan L. Watson

Gentlemen:

Enclosed are my responses to the eight questions which you asked to supplement the record on the low enriched uranium, September 25, 1984, hearing. Also enclosed for your information are the TRTR comments submitted to the Nuclear Regulatory Commission concerning the proposed conversion rule.

TRTR and I are very appreciative of the opportunity we have been given to express our views on this important issue and we thank the subcommittees and their staff for the courtesy and understanding extended.

Very truly yours,

A. Francis DiMeglio

A. Francis DiMeglio
Chairman, TRTR

AFD:cd

Enclosures: Attachment 1
TRTR Comments to NRC

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RHODE ISLAND ATOMIC ENERGY COMMISSION
Nuclear Science Center
South Ferry Road
Narragansett, R.I. 02882-1197

ANSWERS TO ADDITIONAL QUESTIONS

A. Francis DiMeglio
Chairman, TRTR

1. TRTR does not believe that conversion to LEU is necessary to achieve acceptable diversion risk. If conversions are ordered, the proposed rule, subject to interpretation of some wording, could be the basis for orderly conversions. There are provisions which could be interpreted in a way which will be "painful". For example, the rule requires an intermediate enrichment for those reactors which cannot operate with 20% enrichment. Will this mean that if 85 or 90% enrichment is possible, a reactor must convert from 93%? Where will the tradeoff occur between the lifetime of a core and enrichment? At what level of federal funding will the rule become affective? Will all existing fuel be utilized? Will lifetime cores be exempt as the Department of Energy and State recommend or will the Nuclear Regulatory Commission order conversions of lifetime cores also? If generic licensing becomes impossible, will the rule be void? For which experiment and at what level will flux deterioration be a reason for exemption?

   TRTR believes that while ambiguities exist in the proposed rule, the Nuclear Regulatory Commission did endeavor to propose a rule by which conversions could proceed in the least painful manner.

2. TRTR recommends that the Committee not recommend funding for the conversions at this time since it will not contribute significantly to a reduction in diversion risk. This recommendation does not apply, of course, to the Department of Energy Fuel Cycle Assistance Program which has been in effect for over 15 years.

   Instead, TRTR believes that funding should be provided to return to the United States the more than 10 tons of HEU in spent fuel being stored overseas.

   In testimony before your Subcommittees on September 25, 1984, the Department of Energy stated that it had no interest in funding the conversions of lifetime cores. The Department of State said that it agreed that converting lifetime cores did not make much sense at this time.

An examination of the 31 reactors targeted by the proposed rule reveals the following:

Lifetime cores	19
Decommissioning announced	1
Currently shut down	1
High performance (conversion technology unavailable)	3
Currently at 70% enriched	2
Total	26

Of the remaining 5 reactors, 1 may be considered lifetime in spite of its power level because of its operating schedule. At least 3 of the remaining 4 could utilize engineering fixes leading to semi-lifetime cores.

TRTR believes that the mission of the Reduced Enrichment Research and Test Reactors (RERTR) program has been too finely drawn and has been concentrating on only one aspect of the broad task of reducing the proliferation risk from non-power reactors. In fact, as presently constituted, the program will serve very few facilities as shown by the above statistics and few facilities will survive an across-the-board application of the new fuel technology. TRTR believes that the mission of the Argonne Program should be redirected to study all ways of reducing the proliferation risk at non-power reactors including the design of long-life cores. This redirection of the program will demonstrate the commitment of the United States to maintaining and improving nuclear education and research capability, will allow the United States to regain its lost leadership role in this area and will demonstrate to the international community its dedication to no undue proliferation risk without technical regression.

3. There is no formal application or acceptance process for membership in TRTR. Any individual from a non-power reactor facility may participate in TRTR activities and meetings. Meetings are held as often as necessary but at least annually.

The current membership is shown in Attachment 1. As shown on the list, the membership does include representatives from private and Department of Energy reactors. There is no "organization" membership. The chairman is usually from the facility which will host the annual meeting with the understanding that the chairman may not come from a national laboratory facility or a non-United States facility: i.e. the chairman must represent a Nuclear Regulatory Commission licensed facility.

As the membership list shows, all reactors currently targeted by the LEU proposed rule have representatives in TRTR.

The positions of TRTR concerning conversion to LEU have been developed at meetings of the membership.

4. No. I went on to state "TRTR believes that such security already exists since the security plans for most facilities were evaluated by the Nuclear Regulatory Commission against a diversion risk within the last few years and approved."

   As you may know, the Nuclear Regulatory Commission has been reviewing security requirements at non-power reactors and has prepared a draft of proposed adjustments which the Nuclear Regulatory Commission believes would adequately protect the HEU, at least in the short term. Except for provisions against an insider diversion threat, most of the suggested improvements are already in place at most facilities.

5. The Nuclear Regulatory Commission is developing a draft of security measures which they believe will protect HEU, at least in the short term. Using the criteria in the draft, minor adjustments in security plans at a few facilities may be necessary. The costs of such adjustments would not be very high and certainly much less than replacing the fuel.

   Assuming that lifetime core facilities are not converted to LEU, then engineering fixes (long-life HEU cores) for the few remaining reactors could be accomplished during normal fuel replacement. The only additional costs would then be design costs and licensing costs. In fact, long-life cores will ultimately save money over current practices because of reduced fabrication costs, transportation costs and reprocessing costs.

6. The costs involved include the following:

   A. new fuel design
   B. facility modifications (increased crane capacity, increased floor loading capacity, handling tools for modified fuel, etc.)
   C. shipments to reprocessing of HEU
   D. new LEU fuel
   E. in-house costs for relicensing
   F. litigation expense if relicensing hearings are necessary

   Assuming A-F is picked up by the federal government, I would expect that 5 facilities will shut down. This estimate is based on comments to me from the facility supervisors.

   If relicensing litigation becomes necessary and the cost is not picked up by the federal government, all reactors not exempt from the rule become vulnerable. I would expect that few facilities, especially university facilities, would be willing to finance the kinds of litigating in which UCLA was involved.

7. The conversion cost estimates available to me are as follows:

University reactors	12-15 million
National Bureau of Standards	2 million
G. A. Technology (known costs)	1.5 million
Union Carbide	?
General Electric Test Reactor	?
Westinghouse Test Reactor	?

These costs do not include relicensing and manpower costs for document preparations. They do not include lost productivity costs for the individuals preparing licensing documents.

8. The cost of decommissioning research and test reactors has been analyzed in documents NUREG/CR-1756, Volumes 1 and 2 and supplements. These documents considered the costs of decommissioning a 1 megawatt TRIGA reactor and a 60 megawatt test reactor. The documents also considered the actual costs for several reactors which have been decommissioned.

There is no typical university reactor. From the above documents, the following table may be constructed:

FACILITY	REACTOR TYPE	POWER LEVEL	ADJUSTED COST 1981 DOLLARS
Diamond Ordinance Radiation Facility	Pool, TRIGA	250 KW 2,000 MW pulsing	$ 398,000
Ames Lab Research Reactor	Tank, Heavy Water	5 MW	4,629,000
Lynchburg Pool Reactor	Pool	1 MW*	77,600
North Carolina State	Pool	10 KW	**100,000
Oregon State	Solid Homogeneous AGN-201	0.1 W	10,914
Reference Research Reactor, TRIGA		1 MW	1,000,000 to 4,500,000
Reference Test Reactor		60 MW	15,500,000

*Total lifetime generation, 842 MW-hrs. Facility not as radioactive as typical 1 MW facility.

**Changed from NUREG/CR-1756 because of private communication from North Carolina State.

These costs should be regarded only as rough estimates because of the large differences in construction techniques and operating histories of the various facilities. In addition, shipping costs of fuel to reprocessing have risen sharply in recent years to the point where removal of fuel elements from a low-power pool type reactor could approach the total costs of decommissioning the North Carolina State or Lynchburgh reactors.

TRTR MEMBERSHIP LIST

ATTACHMENT 1

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October 24, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

The National Organization of Test, Research and Training Reactors (TRTR) is pleased to submit its comments concerning the proposed rule to limit the use of high enriched uranium (HEU) in its reactors. The 31 or so non-power reactors (NPR) which will be affected by the proposal to convert to low enriched uranium (LEU) fuel are all members of TRTR. TRTR conducted its annual meeting in August, 1984 and these comments represent the consensus developed at that meeting.

The operators of the 31 reactors fully support the goals of no undue risk of diversion of enriched uranium from their facilities. However, they do not believe that the achievement of acceptable risk requires the abandonment of the use of HEU, which will be the result if the proposed rule is adopted. TRTR, therefore, opposes the adoption of the proposed rule for the reasons which follow.

The risk of diversion of HEU from the NPR facilities (and therefore, the necessity for the proposed rule) has not been adequately assessed. Zebroski (1) has examined the relative diversion risks from many different types of facilites which utilize HEU and he concludes that the group of reactors targeted for conversion present the lowest diversion exposure. This, coupled with the fact that these reactors utilize only 10% of the HEU used in domestic research and test reactors, means that conversion of the 31 non-Department of Energy reactors does not significantly affect domestic diversion risk.

The Nuclear Regulatory Commission itself has stated that ....."currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public." The proposed rule, therefore, will reduce an already acceptable risk which in itself is only a small fraction of the overall risk. A broad view of the risk, in perspective to other closely related risks, suggests that the risk reduction benefit for conversion of the targeted reactors is rather small and the total costs are rather high.

TRTR believes that this attempt to reduce the risk to zero of the diversion of any amount, however small, of HEU has precluded discussion of alternatives to the abandonment of HEU.

An obvious alternative to LEU is appropriate security. In most facilities an appropriate level of security already exists and it can be extended to additional facilities if necessary. Recall that the security plans for non-power reactors were evaluated by the Nuclear Regulatory Commission against a diversion risk within the last few years and approved. In fact, protection of non-power reactors against acts of vandalism, theft of equipment and injuries to personnel will in general provide the security level necessary to protect against diversion of HEU.

The Nuclear Regulatory Commission staff has testified on several occasions that there has been no evidence of a theft or diversion attempt at any research reactor. In addition, the Nuclear Regulatory Commission has stated that the intelligence agencies have not identified any threat against such facilities. Nevertheless, the credence given to the remote possibility of successful diversion simultaneously from the number of reactors necessary to obtain material sufficient for a weapon, sets the seeds for future panic. If credence is given by authorities to instant bombs from insufficient material, then future panics are likely to be an unfortunate by-product. The rule may unintenionally and indirectly contribute to a real increase in public risk because of panic.

Another alternative to the proposed rule is engineering fixes, the best example being the use of long-life HEU cores. Already, 18 of the 31 reactors have true lifetime cores with 12 of these having inventories less than 5 Kg. Using the high uranium density fuels being developed by the Department of Energy Extended Life Aluminide Fuel (ELAF) project due to be completed in about one year, more highly loaded HEU fuel elements can be utilized with about double the present burnup limits providing semi-lifetime cores with less than 5 Kg inventory for several more reactors. Because of the longer lifetime of such fuel, fewer elements will be in storage, in the fabrication pipeline and in transit, thereby reducing the proliferation risk in comparison with today's practices.

In testimony on September 25, 1984 before subcommittees of the House Committee on Science and Technology, the Department of Energy stated that it had no interest in funding the conversion of lifetime cores. The Department of State stated that it agreed that converting lifetime cores did not make much sense at this time.

An examination of the 31 reactors targeted by the proposed rule reveals the following:

Lifetime cores	19
Decommissioning announced	1
Currently shut down	1
High performance (conversion technology unavailable)	3
Currently at 70% enriched	2
Total	26

Of the five (5) remaining reactors, several could take advantage of the ELAF programs and operate with in-house inventories of less than 5 Kg.

TRTR believes that the mission of the Reduced Enrichment Research and Test Reactors (RERTR) program has been too finely drawn and has been concentrating on only one aspect of the broad task of reducing the proliferation risk from non-power reactors. In fact, as presently constituted, the program will serve very few facilities as shown by the above statistics and few facilities will survive an across-the-board application of the new fuel technology. TRTR believes that the mission of the Argonne Program should be expanded to study all ways of reducing the proliferation risk at non-power reactors including the design of long-life cores. This redirection of the program will demonstrate the commitment of the United States to maintaining and improving nuclear education and research capability, will allow the United States to regain its lost leadership role in this area and will demonstrate to the international community its dedication to no undue proliferation risk without technical regression.

Another reason given for the proposed rule is that the conversion of domestic reactors will set an example for the international community. TRTR does not believe that the conversion to LEU of a few intermediate power domestic reactors sets the correct example for operators of foreign reactors. In fact, the European non-power reactor community has stated (2) in correspondence to the Nuclear Regulatory Commission that the example being set by the United States is the conversion of its lower power reactors involving only a small fraction of United States HEU traffic, with no conversion of high power level reactors. Comparable conversions overseas will similarily not have a serious effect on HEU traffic overseas. The United States can demonstrate its goodwill towards reduced proliferation risk by arranging for the return to the United States of the more than 10 tons of HEU in spent fuel being stored in Europe.

TRTR is concerned about the use of "generic licensing" as part of the proposed rule. For most reactors, the fuel description is part of the technical specifications: some reactors will require other changes in the technical specifications. If, as a consequence of these changes, a license amendment is required, then a hearing with the opportunity for public intervention is possible. Along with the Advisory Committee on Reactor Safeguards, TRTR believes that before the adoption of a rule which might permit unrestricted intervention ".....the Commission obtain an evaluation of the course, nature, costs and other relevant aspects of previous contested hearings involving non-power reactors to determine if the hearings are serving their intended functions effectively. It may be that the rules regarding hearings involving low power research reactors should be different than those for power reactors". The entire NPR community has been sensitized to the licensing issue because of the recent decision of UCLA to withdraw its application for license renewal after four years of hearings at an estimated cost to UCLA of $500,000. If litigation occurs because of the proposed rule, clearly half of the reactors involved will decommission. TRTR does not believe that generic licensing of a fuel design which has not been tested under abnormal operating conditions is feasible. TRTR recommends that the RERTR program be expanded to qualify fuel element behavior under accident conditions based on the legal criteria used in the UCLA hearings.

Concerning the extent that economics of conversion should influence Commission actions, TRTR believes that in an area where real benefits are minimal and there is already "no undue risk", economic considerations must be paramount. Already RERTR has spent about 35 million dollars: it is estimated that an additional 30 million dollars will be required. Conversion of university reactors is estimated at 12-15 million dollars: conversion of the remaining non-power reactors will require an additional 1-2 million dollars. Clearly, without considering the Nuclear Regulatory Commission and individual facility costs, expenditures are already very high in an area where lower cost alternatives are available for the aversion of risk to the public health, safety and the environment. This is especially true considering the societal costs associated with the proposed rule which will effectively downgrade most reactors and cause the decommissioning of several.

With regard to funding if conversions are mandated by the Nuclear Regulatory Commission, TRTR believes that since these conversions will be based on a change in national policy rather than on some unidentified threat, all conversions should be at federal government expense for all reactors, even those operated by non-federal government organizations. In addition to the direct costs for the new fuel, reprocessing of old fuel and facility modifications, these federal funds should be available for relicensing, including litigation and for lost overhead funds for the facility staff involved in the relicensing procedure.

TRTR urges the Commission not to adopt the proposed LEU rule and pledges the cooperation and support of its membership in developing and implementing alternatives.

Very truly yours,

A. Francis DiMeglio
Chairman, TRTR

AFD:cd

(1) See Attachment 1

(2) See Attachment 2

DON FUQUA (Fla.), Chairman

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October 10, 1984

Dr. Paul J. Turinsky
Department of Nuclear Engineering
North Carolina State University
Raleigh, NC 27695-7909

Dear Dr. Turinsky:

Thank you for your excellent testimony at our September 25, 1984 hearing on the Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel.

We would like to supplement the record of the hearing with your responses to the attached questions. We would appreciate receiving your responses within three weeks from the date of this letter. Please forward this information to the Subcommittees' office, Room B-374 Rayburn House Office Building, Washington, D.C. 20515, to the attention of Dr. Harlan L. Watson.

We appreciate your cooperation in this matter.

Sincerely,

Don Fuqua
DON FUQUA, Chairman
Committee on Science
and Technology

Marilyn Lloyd
MARILYN LLOYD, Chairman
Subcommittee on Energy
Research and Production

Attachment

Additional Questions for Dr. Turinsky

1. Suppose the NRC decides to order the conversion of at least some research and test reactors. How would you recommend that this proceed in the least painful manner?

2. What actions would you recommend this Committee take with regard to this matter?

3. Your testimony dwelt on the cost aspects of conversions. Do you see benefits from converting, and if so, are they greater than, equal to, or less than the costs?

4. To what extent can some of the traditional nuclear engineering training be done with computer simulators rather than relying on reactors?

5. If some of the university reactors do close down, couldn't some of the training and research activities be shifted to the DOE reactors provided access was made available?

6. Do you have any sort of quantitative measure of the educational, research and service benefits derived from the university reactors?

7. What is the typical operating cost of a university reactor?

8. How much more expensive is it to educate a typical nuclear engineer as compared with other engineering fields?

9. You noted that recent nuclear engineering enrollments have declined substantially. Are the number of universities offering degrees in nuclear engineering also decreasing?

North Carolina State University
School of Engineering

Department of Nuclear Engineering
Box 7909 Zip 27695-7909

October 26, 1984

Dr. Harlan L. Watson
Subcommittee on Energy Research and Production
Room B-374, Rayburn House Office Building
Washington, DC 20515

Dear Dr. Watson:

Attached are my answers to questions the House Committee on Science and Technology asked me concerning conversion of research and test reactors to low-enriched unanium fuel. Thank you for the opportunity to provide further input to this Committee.

Sincerely,

Paul J Turinsky

Paul J. Turinsky
Past Chairman, Nuclear
Engineering Department Heads'
Organization

Enclosures

cc: Dr. A. F. DiMeglio
Dr. Glen Knoll

Answers of Dr. Paul J. Turinsky to questions asked by the Committee on Science and Technology on conversion of research and test reactors to low-enriched fuel.

QUESTION:	Suppose the NRC decides to order the conversion of at least some research and test reactors. How would you recommend that this proceed in the least painful manner?
ANSWER:	If the NRC were to order the conversion of some research and test reactors, licensing should be addressed in as generic a fashion as possible. That is, the affected reactors should be grouped into similar reactors and the NRC should generically license each group. The generic licensing of each group will result in generic licensing limits. If the licensee could demonstrate that their reactor satisfies the applicable generic licensing limits, NRC permission to convert should be granted. In this way, intervenor actions concerning licensing limits would be handled somewhat collectively. However, since intervenors could still challenge the licensee's claim that their reactor satisfies the generic licensing limits, the potential for protracted hearings would still exist. There is no way of implementing the proposed rule without a major adverse impact on university reactors' teaching, research and service programs.
QUESTION:	What actions would you recommend this Committee take with regard to this matter?
ANSWER:	The proposed NRC conversion rule states that conversion is required contingent upon federal government funding for those reactors where the federal government currently provides the fuel. I believe the Committee has gathered convincing data that conversion of domestic reactors results in minor benefits and high costs. I urge this Committee to recommend that no funds be made available to complete the conversions. Without funds the proposed rule would be mute with the exception of the few reactors owned by industry. I would hope this Committee could in some fashion address these remaining reactors.

QUESTION: Your testimony dwelt on the cost aspects of conversion. Do you see benefits from converting, and if so, are they greater than, equal to, or less than the costs?

ANSWER: This Committee has heard extensive testimony which indicates that the benefits from conversion are minor but that the costs of conversion are high. Three different federal government groups, the Department of Energy, Advisory Committee on Reactor Safety, and National Bureau of Standards, I interpreted to all reach this conclusion. Needless to say, those of us who utilize or operate reactors have reached this same conclusion. Only the Department of State and NRC believe the benefits outweigh the costs, both in dollars and lost reactors. The Department of State's major concern appears to be diversion of enriched uranium from foreign reactors. Their belief is that if the US sets the example by converting non-DOE domestic reactors, foreign governments will adopt a similar policy. Recent past history concerning fuel reprocessing does not support this belief. In addition, I believe that one will find that most highly enriched uranium reactors in foreign countries are located at government laboratories. These laboratories most closely parallel DOE laboratories, whose reactors are not being forced to convert. Hence, the analogy is very weak regarding which reactors in the US and in foreign countries are being asked to convert.

QUESTION: To what extent can some of the traditional nuclear engineering training be done with computer simulators rather than relying on reactors?

ANSWER: Nuclear engineering training and education cannot be replaced by computer simulators. At North Carolina State University we train the operators on our reactor for electric utility companies. These utility companies own one or more simulators costing each in excess of six million dollars, which the operators also train on. If computer

QUESTION: Do you have any sort of quantitative measure of the educational, research and service benefits derived from the university reactors?

ANSWER: To quantify the educational, research and service benefits derived from university reactors is a difficult task. Nationwide the following number of nuclear engineering degrees were awarded in 1983: B.S.- 676, Masters - 325, Ph.D. - 124. The universities which produced most of these degrees operate reactors. What fraction of the education time a student utilizes the reactor is not tabulated on a national basis. At NCSU the following information is applicable. Four of the nine undergraduate nuclear engineering courses required in the baccalaureate degree program utilize the reactor. Three of the eight graduate courses comprising the core graduate curriculum utilize the reactor. Over the past few years, 45% of masters and 35% of doctorate students have utilized NCSU's reactor in completing their theses. This data clearly demonstrates that the reactor is an integral part of a nuclear engineering student's educational experience.

The extent of research and service activities at university reactors is very dependent upon the reactor's capabilities. Low power reactors (less than 1 Mw) are mainly used in teaching and do not have the neutron flux levels which allow extensive research and service programs. The high power university reactors' research and service programs vary in financial support levels from tens of thousands to several million dollars per year. As I testified before this Committee, a wide range of research is conducted on university reactors. Further information on the research conducted on reactors can be obtained from the "Proceedings of the International Symposium on the Use and Development of Low and Medium Flux Research Reactors." Much of this research utilizes the neutrons as probes to measure the simulation could replace reactors, would utilities being spending several hundred thousand dollars per year to train on the NCSU reactor? Real operational and experimental experiences cannot be replaced by computer simulation. One cannot simulate such things as placing a flux wire in th core, removing it, and counting it to determine the flux spatial profile. The other point to be noted is that at NCSU and at a number of other universities operating reactors, the major use of the reactor is as a neutron source for teaching, research and service. Reactors continue to be the most economical source of neutrons for a wide range of applications. Testimony I presented to this Committee indicates the vast range of such activities conducted on university reactors. Computer simulators don't produce neutrons!

QUESTION: If some of the university reactors do close down, couldn't some of the training and research activities be shifted to the DOE reactors provided access was made available?

ANSWER: Unless a university is located very near to a DOE reactor, this would not be possible. With the class schedules students have, it is not possible to be out of town a day or two without missing a number of classes. The same situation applies to faculty in regard to conducting research off campus. The other point to note is that most DOE reactors have neither been designed nor operate with teaching as the objective. The DOE reactors are mainly reactors dedicated to research. They normally operate at full power for extended periods to assure a constant source of neutrons to the researchers. This type of operation is in conflict with teaching where reactor startups, shutdowns and transients are required.

chemical, molecular and nuclear makeup of matter. Applications range from environmental research to microelectronics research. At NCSU's reactor, EPA maintains a laboratory at our facility to do environmental research utilizing the neutron activation analysis technique. If these high power reactors were to close down or have degraded performance due to conversion, many research areas would be adversely impacted.

QUESTION: What is the typical operating cost of a university reactor?

ANSWER: Operating costs are dependent upon reactor power level and utilization. Not accounting for the cost of fuel, which DOE provides assistance for, they range from several tens of thousands to hundreds of thousands of dollars per year. At NCSU, the base operating budget for our reactor is approximately $340,000 per year.

QUESTION: How much more expensive is it to educate a typical nuclear engineer as compared with other engineering fields?

ANSWER: Nuclear engineering undergraduate education is considerably more expensive than other engineering disciplines for two reasons. Firstly, the cost of operating a reactor can be substantial and there is normally no equivalent cost for other engineering disciplines. Secondly, the declining student enrollments have led to high costs per student since fixed costs, e.g., reactor and faculty salary costs, are allocated across a smaller number of students. One could argue that faculty size should be reduced, but one reaches a point where curriculum coverage and not student-to-faculty ratio becomes the key issue. I know of no national figures on the cost of educating nuclear engineers versus other engineers. At NCSU the cost per nuclear engineering degree is approximately three times the average cost of an engineering degree. Since NCSU's nuclear engineering program has a large student enrollment and high student-to-faculty ratio versus a number of nuclear engineering programs, one can surmise that the costs per degree will be even higher at a number of other universities.

QUESTION: You noted that recent nuclear engineering enrollments have declined substantially. Are the number of universities offering degrees in nuclear engineering also decreasing?

ANSWER: There are currently 44, 50 and 35 institutions which offer, respectively, B.S., Masters and Ph.D. degrees. However, of these institutions, approximately 20 institutions now produce the large majority of nuclear engineering graduates. Several years ago, when B.S. and masters enrollments were 26% higher, approximately 30 institutions would have been so classified. In the last several years, eight established nuclear engineering programs have either folded, been merged with larger programs, or become inactive. This has occurred due to declining enrollments and lack of research support. More casualties are to be expected unless relief is obtained via increased financial support and a healthier industry. Ironically, demand for nuclear engineering graduates is strong and projected to remain so by both industry and DOE manpower studies.

APPENDIX 2

ADDITIONAL LETTERS AND STATEMENTS FOR THE RECORD

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

October 17, 1984

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
U. S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

During our review of NRC testimony from the hearing on Conversion of Research and Test Reactors to Low Enriched Uranium Fuel, we discovered a factual error that we wish to correct for the record. This error occurs on lines 638 and 642 of the stenographic minutes of the hearing record. Our correction is as follows:

> The final NRC FY 1985 appropriation cut was $20 million (not $40 million) and, accordingly, this cut represents a little less than five percent (not ten percent) of NRC's total FY 1985 budget.

We hope that you will agree to append our correction request to the hearing record and to footnote the appropriate place where the correction should be made. We apologize for this inconvenience.

Since this hearing was conducted jointly by the Subcommittees on Energy Development and Applications and Energy Research and Production, we have addressed an identical letter to Chairman Marilyn Lloyd.

Sincerely,

Edward Fay

Carlton Kammerer, Director
Office of Congressional Affairs

ENZO RICCI, Ph.D., M.S.
996 West Outer Drive
Oak Ridge, Tennessee 37830
September 19, 1984

Honorable Don Fuqua, Chairman
House Committee on Science and
Technology
2269 Rayburn House Office Building
Washington, D. C. 20515

Honorable Marilyn Lloyd, Chairman
House Subcommittee of Energy
Research and Production
2334 Rayburn House Office Building
Washington, D. C. 20515

Honorables Don Fuqua and Marilyn Lloyd:

Proposed Rule on Conversion of Non-Power Reactors from Highly Enriched Uranium (HEU) to Low Enrichment Uranium (LEU) Fuel

On July 6, 1984, the National Regulatory Commission (NRC) proposed the rule "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors." This proposed rule was published for comment in the Federal Register, Vol. 49, No. 131, July 6, 1984, pp 27769-72. The comment period would have expired on September 4, 1984, but it has now been extended by the NRC until November 2, 1984.

I understand that appropriations for this NRC proposed rule will be discussed at a joint meeting of the House Subcommittees of Energy Research and Production and of Energy Development and Applications, on September 25, 1984.

I am a member of the National Board of Directors of the American Nuclear Society (ANS). In this capacity I have been following and influencing developments related to the proposed rule. I am also one of Mrs. Lloyd's constituents, and would like to inform both of you about some controversy that surrounds this issue. It seems that a discussion of appropriations would involve consideration of the effectiveness and usefulness of the rule and, therefore, of its general acceptability.

The ANS has expressed its position on HEU/LEU conversion officially and unofficially in various occasions. M. Levenson (past ANS President), J. M. Hendrie (ANS President) and J. W. Lucey (ANS Education Division) sent letters to the NRC Chairman on March 19, June 11, and May 23, 1984, respectively. Hendrie's letter enclosed a copy of a relevant paper by E. L. Zebroski.* Presently, the ANS is preparing a letter commenting on the proposed rule. I understand that opposition to the proposed rule will be expressed by organizations invited to the September 25, 1984, meeting.

I intend to encourage the ANS to oppose the proposed rule (in its forthcoming letter to the NRC) at least on the following grounds:

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*Edwin L. Zebroski, "Relative Diversion Exposures of HEU: Relation to University Reactors," 1984 ANS Annual Meeting, New Orleans, LA, June 3-8, 1984. Zebroski has been invited to make a presentation at the September 25, 1984, joint meeting.

1. The justification given by the NRC for the rule (p 27769) follows:

> "The proposed rule is intended to reduce the risk of theft or diversion of HEU fuel used in non-power reactors and the consequences to public health, safety and the environment from such theft or diversion. The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use."

It appears, however, that the foreseeable reduction of risk is minimal in comparison with the potentially serious detrimental effects that the rule can cause to the essential activities of education, research, radioisotope production and activation analysis. As expressed in Levenson's March 19 letter (attached) the licensed university HEU reactors represent only about 15% of the U.S. HEU reactors. This argument against the rule is supported by the previously mentioned paper by Zebroski. The author states:

> "to make a single basic nuclear explosive, it would take the in-core fuel inventory of at least three of the research reactors with largest inventories, and about nine of the reactors with the smallest inventories."

Thus, any group that were to attempt theft or diversion of HEU to make an explosive would have to carry out at least three successful, almost simultaneous strikes. Zebroski also comments on the rule's expressed hope that the reduction in domestic use of HEU may encourage similar action at foreign research reactors. He points out that, even if foreign research reactors were converted, this would not materially affect the existing risk associated with the 20 tons of HEU already exported by the U.S.

In addition to the serious consequences of university and research reactor shutdowns that the proposed rule may cause, conversion to LEU is costly. This will be pointed out at the joint meeting by invited organizations, in contrast with the minimal benefits that the rule may bring.

In conclusion, the reduction of risk that the rule would provide (at great cost) seems to be trivial, considering the large amounts of HEU existing in the U.S. and abroad that would not be affected. In fact, the conversion of U.S. university reactors could well be interpreted abroad as an empty (or worse, naive) gesture and, thus, have the opposite effect to that intended by the NRC.

2. To facilitate conversion safety reviews, the NRC is considering "generic envelopes of safety limits" that could be applied to several types of nonpower reactors (p 27770). The NRC asks for comments on this approach (p 27771), and also on the extent that the economics of conversion should influence NRC actions (p 27770).

The Advisory Committee on Reactor Safeguards of the NRC studied the proposed rule and, in its report to the NRC Chairman*, expressed that if conversion requires a license amendment, the way might be opened for "unrestricted intervention." Considering both the significant core changes that the conversion would require for many reactors, and the virulence of intervenor groups, it is unlikely that relicensing after conversion could proceed without public hearings. In this regard, it is sobering to recall that the Committee to Bridge the Gap (CBG) succeeded in causing the shut-down of the UCLA research reactor, after UCLA spent several hundred thousand dollars in relicensing public hearings. The CBG has pledged to challenge all university and research reactors due for NRC relicensing.

I suggest that public hearings are a real possibility, and can impact the economics of conversion. This possibility should definitely influence NRC actions. In particular, if the rule were to be enacted, it should be essential that it assure Federal financing of relicensing proceedings, including public hearings. Otherwise, many university and test reactors will likely be forced to shutdown permanently.

I feel that these are objective and serious objections to the proposed rule. I believe that the rule should be dropped.

Sincerely,

Enzo Ricci

Enzo Ricci
Phone: Home (615)483-0[illegible]66
Bus. (615)574-8138

Attachment

cc: A. Francis Di Meglio
J. M. Hendrie
L. Ventre, Jr.
NRC Secretary

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*J. C. Ebersole, ACRS Chairman, "ACRS Report on Proposed Rule for Limiting the Use of HEU in Domestic Research and Test Reactors," June 18, 1984.

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March 19, 1984

Dr. Nunzio J. Palladino, Chairman
U.S. Nuclear Regulatory Commission
Washington, DC

Dear Dr. ~~Palladino~~:

Conversion of Fuel Elements of Small Reactors from Highly-Enriched to Low-Enriched Uranium

The American Nuclear Society has been following the NRC activities concerning the HEU/LEU Conversion. We understand that the Commission is preparing to issue a ruling directing all licensed reactors which use HEU fuel elements to "convert promptly" to LEU. We believe there are several issues that should be recognized in framing such a ruling or directive:

1. Education is one of our highest national priorities because of its relevance to U.S. progress and security. Research/teaching reactors are of major importance in assuring an adequate supply of professionally trained workers for the essential fields of nuclear engineering, nuclear physics, nuclear chemistry and activation analysis.

2. Licensed teaching/research reactors are an important source of short-lived isotopes for medical research and diagnosis. Reactor shutdowns would probably lead to the cancellation of many of these programs.

3. While conversion feasibility was demonstrated at Argonne for some reactors, detailed technology for others is still undemonstrated. Further, reload to constant power but reduced flux can significantly affect important programs in radioisotope production and activation analyses.

4. The concept that a HEU/LEU conversion in the U.S. is a good role model for the rest of the world seems to ignore two factors:

    a. Converting the licensed university reactors probably results in converting less than 15% of the U.S. HEU reactors.

b. The offshore concern has been the temptation for a non-weapons government to proceed with weapons technology and then suddenly divert the HEU. It would hardly seem that such a concern exists in the U.S.

5. Since such a directive or ruling seems to be motivated largely by considerations of foreign policy and not by concerns for public safety (in the accident consequence sense), we believe it is appropriate that the U.S. government bear the full cost of any ordered replacements and/or modifications or resulting relicensing. The Honorable Messieurs Ottinger, Markey and Wolpe appear to recognize this in their letter to you of January 26, 1984. It is very important that the timing of the directive should be coordinated with the timing of the funding.

Because of the importance of this matter to both medical research and education and the very real risk that unintended consequences will occur as a result of such a directive, I urge that full consideration be given to the above factors before the directive is finalized.

Sincerely yours,

Milt

Milton Levenson

ML/pw

cc ANS Executive Committee
O. J. Du Temple
E. Ricci

TESTIMONY OF GA TECHNOLOGIES INC.

BEFORE A JOINT HEARING OF THE

SUBCOMMITTEES ON

ENERGY DEVELOPMENT & APPLICATIONS

AND

ENERGY RESEARCH & PRODUCTION

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

SEPTEMBER 25, 1984

ROBERT H. CHESWORTH, DIRECTOR
TRIGA REACTOR DIVISION

INTRODUCTION

GA Technologies Inc. (GA) has a dual interest in the proposed NRC rulemaking concerning the conversion of domestic HEU-fueled research and test reactors to LEU fuel. GA owns and operates a 1500 KW TRIGA Mark F reactor at its San Diego facility which is currently fueled with long-lived 70 percent enriched uranium zirconium-hydride fuel so the implications of mandated conversion is of serious concern.

GA also fabricates and supplies LEU uranium zirconium-hydride fuel for TRIGA and non-TRIGA research and testing reactors throughout the world. The proposed rulemaking would probably accelerate the conversion of certain domestic HEU fueled reactors and thus would result in the production of LEU fuel on a more ambitious schedule than would be typical if the rule were not in effect.

The potential effect on the rulemaking is described below from the standpoint of these two different points of view.

A. Need for and Potential Impact of Conversion of TRIGA Mark F Reactor to LEU Fuel.

The TRIGA-FLIP* fuel which is installed in the TRIGA Mark F reactor in San Diego nominally satisfies the definition of high enriched uranium (HEU) fuel, but the fuel is in fact 70 percent enriched in Uranium 235. Thus its value in developing a nuclear explosive device is severely limited relative to fully enriched uranium. Furthermore, the uranium-erbium-zirconium hydride FLIP fuel is difficult to reprocess and extract the uranium in a pure form. The contained erbium, about 1.5 weight percent, is a very efficient neutron poison and must be completely removed if the uranium is to be used in a weapon. Also the uranium zirconium-hydride requires a somewhat elaborate and expensive reprocessing process, compared to aluminum plate or uranium dioxide fuel; consequently, the DOE has elected not to reprocess spent TRIGA fuel elements but stores the elements adjacent to the reprocessing facility at the Idaho National Engineering Laboratory.

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*Fuel Lifetime Improvement Program

Another major consideration regarding the need for conversion of the TRIGA Mark F reactor to LEU is the degree of physical security associated with the reactor fuel. The TRIGA reactor facility is located on the premises of GA Technologies' main plant. All unsecured gates are manned by security guards 24 hours per day and entrance to the plant is closely controlled. Further, entrance to the reactor room is locked and access controlled by the reactor supervisor. During off hours, there is a special protective alarm system that will elicit an immediate response if an unauthorized individual gains access to the reactor room. The reactor tank is secured as a locked "fuel storage vault" and any tampering with the lock will also elicit an immediate response from security forces. Finally, the current and contemplated operation of the TRIGA Mark F reactor will maintain the individual fuel elements at a radiation level significantly above 100R/Hr at three feet in air at all times.

In summary, it is submitted that the presence of 70 percent enriched fuel in the GA TRIGA Mark F reactor does not represent a proliferation risk because the fuel is highly protected, is extremely radioactive, and is in a chemical form that would be very difficult and expensive to purify. It simply represents a very unattractive target for diversion.

The impact of an imposed or mandated premature conversion of the TRIGA Mark F reactor to LEU fuel consists of predictable penalties in terms of cost and schedule and unpredictable or indetermininate delays due to hearings associated with relicensing.

The uncovered costs for the proposed conversion to LEU are large with no prospect for government reimbursement for reactors owned in the private sector (e.g., GA Technologies). The known uncovered costs to GA are summarized below:

Preparation of Safety Analysis Report	$ 100,000
Cost of Replacement LEU Core	1,000,000
License Amendment Fee	25,000*
Shipping HEU to Disposal	75,000
Reprocessing Cost for HEU, with Credit	300,000
Total Known Costs	$1,500,000

Replacing the existing HEU core before its end-of-life without reimbursement means that the several megawatt-years lifetime still available in the core will be wastefully destroyed. It will further result in increased shipping traffic of HEU fuel with its attendant armed guard escorts and associated costs.

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*For GA Technologies, this fee may be lower than the $46,000 maximum because of extensive prior experience with LEU fuel.

One of the most important negative impacts of a mandated conversion to HEU fuel is the requirement for 30-day public notice for license amendments involving fuel changes. Since there are anti-nuclear groups waiting to "pounce" upon any public notice (remember UCLA), mandated fuel conversions will almost certainly result in public hearings and litigation for facilities required to install LEU fuel.

Specific to the possible premature conversion of the TRIGA Mark F reactor to LEU fuel is the probably negative impact on the DOE-sponsored SP-100 irradiation program. Under contract to DOE, GA is planning to commence an irradiation program involving thermionic cells beginning in November of 1984 in support of the U.S. Space Power Development Program. This irradiation program will involve reactor operation 24 hours per day, 7 days per week for approximately one year. Premature shutting down of the TRIGA Mark F reactor for an indefinite delay (related to relicensing) would have a very adverse affect on this program. Also the neutron spectrum of the converted reactor would shift somewhat, requiring design modifications to the irradiation specimens.

B. GA's Readiness as a Reactor Fuel Vendor to Supply the Required LEU Fuel.

Following the adoption of policies by the U.S. Government to limit, with some notable exceptions, export of fuels to those enriched to less than 20 percent in U-235, GA undertook, starting in 1977, a rigorous program to develop uranium zirconium-hydride fuels with higher uranium concentrations (up to 3.7 grams U/cc) while limiting the enrichment to less than 20 percent in U-235. This program was carried out largely with company funding with partial support provided by the DOE-sponsored RERTR Program.

Under the LEU fuel development program at GA, the performance of uranium zirconium-hydride fuels with uranium concentrations up to 45 weight percent has been demonstrated by evaluation of the parameters listed below:

Fabricability
Metallurgical examination
Fission product release
Physical properties
Hydrogen pressure
Quench testing
Cycling/pulse testing
In-pile testing

Fabricability verification was conducted by the production of about 100 pieces of uranium zirconium-hydride fuel by the standard production techniques of induction melting and furnace hydriding. No difficulties were experienced with the fabrication processes although none were anticipated since the uranium volume is still less than 20 percent in the 45 weight percent alloy. The results of metallographic and microprobe tests indicated that the grain structure, phase distribution, and homogeneity were well within normal and acceptable limits.

Following the fabricability testing and metallurgical examinations, further tests were conducted in the areas of fission product release determination, hydrogen pressure measurements, and quench testing from 1200°C. Again, the results were completely satisfactory and within acceptable limits.

The success of the TRIGA research reactor over the past 26 years can be closely related to the prompt negative temperature coefficient of reactivity and related safety characteristics. Thus a high priority item in evaluation of the LEU fuel was determination of the temperature coefficient. Nuclear design and analytical studies have shown that the prompt negative temperature coefficient for the 20 weight percent uranium fuel is essentially the same as that for standard fuels over the temperature range of interest (20° to 700°C). The prompt negative temperature coefficient for the more highly loaded LEU fuel shows a temperature dependence, whereas the coefficient is relatively constant for standard fuel. The value of the prompt negative temperature coefficient of reactivity is slightly lower for the 45 weight percent uranium fuel; however, it is still large and significantly higher than the prompt negative temperature coefficients for any other type of reactor fuel.

Inclusion of erbium burnable poison in the TRIGA LEU fuel has enabled initial core lifetimes of up to 7500 MWD to be predicted for the 45 weight percent uranium fuel. This long reactivity lifetime results in the lowest predicted cost per MWD of any of the LEU-fuels currently commercially available.

The final demonstration of the TRIGA-LEU fuel (up to 3.7 gm/cc) was performed by a full-scale, long-term fuel burnup test in the 30 MW Oak Ridge Ractor (ORR) as part of the U.S. Department of Energy RERTR Program managed by Argonne National Laboratory. A standard geometry 16-rod TRIGA LEU cluster containing uranium loadings of 20, 30 and 45 weight percent uranium was placed under test beginning September 1979 and testing was completed in November 1983. The fuel rods containing 20 and 30 weight percent uranium attained design burnups (35 percent and 40 percent, respectively) in May of 1982 and were removed from the test cluster. After a suitable cooling period, these rods will be subjected to a limited post-irradiation examination, although initial examination reveals no apparent dimensional changes or anomalous behavior. The seven rods containing 45 weight percent uranium were placed back into the reactor and were irradiated to a burnup of about 65 percent (design burnup is 50 percent). The fuel performed completely satisfactorily although some anomalies in the cladding at 65 percent burnup are under continuing investigation.

The LEU uranium zirconium-hydride fuel has successfully completed all essential development testing and is now being offered commercially in both the 20 weight percent and 45 weight percent uranium concentrations for existing TRIGA reactors and as a conversion fuel for plate-type reactors. LEU fuel elements have been delivered to reactors in Malaysia, Taiwan, Yugoslavia and Thailand and entire core loadings of 20 weight percent fuel have been fabricated for a new 3.0 MW TRIGA Mark II reactor in Bangladesh and for the upgrading/conversion of the plate-type PRR-1 reactor in the Philippines. The TRIGA Fuel Fabrication Facility has a capacity of five cores per year with existing equipment and manpower (one shift per day). This capacity could be increased significantly with minimum increase in equipment, should requirements dictate.

Statement of Jack Eckert, Vice President and Division Head, Naval Nuclear Fuel Division, Babcock & Wilcox Company, before the Subcommittees on Energy Development and Applications and Energy Research and Production, Committee on Science and Technology, U.S. House of Representatives, September 25, 1984.

Chairman Fuqua, Chairman Lloyd, and Members of the Subcommittees on Energy Development and Applications and Energy Research and Production.

I am Jack Eckert, Vice President and Division Head, Naval Nuclear Fuel Division of Babcock & Wilcox Company which is a subsidiary of McDermott, Incorporated.

It is a pleasure for me to have the opportunity to describe our involvement in the Reduced Enrichment Research and Test Reactor (RERTR) program. Since time did not permit our personal presentation, we have prepared this document presenting our capabilities and perspective.

The Naval Nuclear Fuel Division (NNFD) of Babcock & Wilcox is located in Lynchburg, Virginia and is the sole U.S. Fabricator of aluminum clad plate-type fuel for research and test reactors.

NNFD re-entered the fuel-element fabrication business in 1981 after previous involvement in the late 50's through 1966. Our facility, which is totally guard-force secured and access-limited, covers 600,000 sq. ft. and employs approximately 2100 people. Approximately 60 of these employees and 30,000 sq. ft. of shop area are involved in the Research and Test Reactor fuel operation.

Our involvement is strictly as a fabricator of fuel assemblies to the design and specification established by laboratories, universities and/or government agencies. We receive uranium as customer-supplied materials and through a series of reasonable sophisticated manufacturing steps and intense quality control and nuclear materials control procedures, encapsulate the uranium and form the shapes required by our customers. Our challenge is to assemble the appropriate materials in such a way that all quality and safety aspects of a customer's design is achievable in an efficient manner.

Our processes and procedures are similar regardless of the fuel type (oxide, aluminide, silicide) and uranium enrichment level (either high or low). We have manufactured high enriched uranium (HEU) fuel elements of oxide and aluminide and low enriched uranium (LEU) fuel elements of aluminide and silicide.

Babcock & Wilcox's involvement in low enriched uranium fuel began in the late 1950's in conjunction with Oak Ridge National Laboratory. Our most recent involvement has been as a result of an Industrial Participation Agreement with Argonne National Laboratory to produce two full size LEU elements for the Oak Ridge Reactor made with uranium silicide. A key target of this effort was detailed research on bonding of fuel and cladding. Our LEU silicide elements have successfully performed in operation at Oak Ridge and in a foreign reactor.

We presently are under contract to supply a total of 60-80 elements per year to the Universities of Missouri, MIT, Michigan, Lowell, Rhode Island and Virginia and 28 elements per year to Union Carbide Medical Products Division. With the exception of Michigan, for whom we are presently making LEU elements, we understand that these organizations are considering the merits, problems and costs of converting to LEU. There are additionally several other universities with "lifetime cores" whose usage rate is low but whose elements or plates are compatible with our manufacturing who may also be reviewing an LEU decision.

We recognize that not all research and development is complete on LEU fuels. In order for conversion of some reactors to LEU without giving up performance, higher density fuels will need to be researched and developed. We do not know if or what fabrication problems these new designs may present.

Additionally, Babcock & Wilcox is not in a position to evaluate the reactor operating and performance considerations of conversion to LEU elements.

With these two qualifiers in mind - all development is not yet complete and operating performance aside - Babcock & Wilcox can make some input to the LEU decision process.

1. The cost to make an element using low enriched uranium fuel to presently developed densities is not significantly different from making the same element using high enriched uranium. This statement pertains to the fabrication cost, not uranium cost, fuel cycle changes, etc. The processes are essentially the same for either enrichment, differing only in yields due to the higher density loading (uranium per volume) of LEU plates. Future density increases may necessitate costs for developing new processes and manufacturing techniques.

2. NNFD has sufficient capacity to produce all the LEU conversion elements needed given a reasonable schedule and phase in period. Some equipment may be needed (i.e., furnaces) where machine cycles exceed shift hours.

3. Any discussion of overall cost impact needs resolution of such points as standardization of plate designs, fuel cycle changes, performance adjustments, total number of reactors affected and time span to do the work.

Babcock & Wilcox is proud of the role it plays in the Research and Test Reactor programs and is ready to assist and support our customers and government programs.

Thank you.

Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

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September 1984

ISSUE BRIEF

The Use of Atom Bomb Material in Civilian Research Reactors

Highly enriched uranium* (HEU), a nuclear-weapons material, is also used as fuel for many research reactors throughout the world. While concerns over the proliferation of nuclear weapons have focused primarily on plutonium, a byproduct of power reactors that can be used in weapons, the use of HEU in civilian research represents a more immediate threat to international security. The issue of HEU use is now at a critical point because the Nuclear Regulatory Commission (NRC) has proposed a rule to require those research reactors it licenses to convert from HEU to lower-enriched uranium unsuitable for weapons. As virtually the exclusive supplier of HEU for research reactors throughout the world, the United States is in a position to take the lead in discontinuing its use.

The Dangers of HEU

There are currently 137 research and test reactors in 34 countries which use HEU as fuel. More than a third of these reactors (45) are in the United States. According to data from the Energy Department, the annual requirement of U-235, the fissile isotope contained in HEU (see note below), for the world's reactors is over one metric ton of which the United States provides 99 percent. There are 4000 kilograms in circulation at any one time -- enough for at least 205 atomic bombs on the basis of a conservative estimate of 20 kilograms per weapon.

The United States has exported some 23,590 kilograms of HEU (containing 16,980 kilograms of U-235) to 43 nations from the start of the Atoms for Peace program through 1982, according to data assembled by David Albright of the Federation of American Scientists (see table and graph). Currently, the United States is exporting about four to five hundred kilograms of this bomb-grade material each year. There have been, however, a number of years when the exports far exceeded this current annual demand.

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*Highly enriched uranium is uranium that has been enriched in the fissile isotope U-235 from the naturally occurring level of slightly less than one percent to as high as 90 percent for use in weapons and research reactors.

Although the amounts of HEU at many of the smaller domestic and foreign research reactors are usually below the 20 kilogram quantity often cited as necessary for a weapon, they still pose an unwarranted proliferation risk. Dr. Theodore Taylor, a former nuclear weapons designer and a member of the board of Nuclear Control Institute, stated at a recent meeting of the NRC that the existence of even one or more kilograms of HEU in civilian research programs is extremely dangerous:

> It is very important for the Commissioners, in order to make rational decisions about the consequences of theft of uranium-235, to know what are the minimum quantities of uranium-235 necessary to make a weapon. I can say flatly that I would be very concerned about theft, clear evidence of theft, of a kilogram or more of highly enriched uranium, and I think everyone should be. From the point of view of one who has designed nuclear weapons, a kilogram or more of 93 percent enriched uranium certainly is a significant quantity.

One of the reasons cited by Dr. Taylor for being concerned about kilogram quantities of HEU is the possibility that stolen material will be used in an implosion type of fission device which radically decreases the amount necessary for an explosion. Dr. Taylor, who in addition to being a weapons designer also designed one of the most commonly used research reactors (the TRIGA) throughout the world, stated that he could see no reason for HEU to be used as a reactor fuel under any circumstances. He asked that the "national benefits" of HEU be weighed against the risks of theft or diversion before any exception is made.

Despite the weapons implications of even small quantities of HEU, the methods used to protect and track the material are often extraordinarily weak. The principal factor contributing to lax security at the smaller reactors in the United States is that most are owned and operated by universities reluctant to institute security measures that are expensive and inappropriate to a university environment. Numerous instances of such security problems as lost keys, defective alarm systems, open access to sensitive areas and the storing of HEU in filing cabinets have been documented by Daniel Hirsch, President of the Committee to Bridge the Gap. The NRC security requirements for university reactors are far from rigorous, and the Commission is not disposed to press the universities too hard on infractions.

The United States has also had trouble tracking and assuring the physical security of the HEU which it sends abroad. In a report issued in August of 1982, the General Accounting Office found that "[t]he Department of Energy's central computerized system used for tracking all U.S. highly enriched uranium exported to foreign countries is incomplete and inaccurate." According to the GAO, the various tracking systems are not coordinated and each system only provides one segment of the overall picture, making it impossible to establish an accurate inventory for each country.

The GAO also found that U.S. officials assigned the task of assessing physical security arrangments have had trouble gaining access to foreign facilities using U.S. HEU and that intervals between visits have become lengthy. Also, a program instituted in 1968 to take back spent HEU fuel (which is still weapons useable) has been largely unsuccessful and only a small percentage of the fuel has been returned.

Efforts Toward a Solution

With increased awareness of the dangers of nuclear proliferation in the wake of the Indian explosion, a consensus developed that the use of HEU in civilian research programs presents an unwarranted proliferation risk and should be discontinued in view of the feasibility of converting to low enriched fuels. The summary report of the International Fuel Cycle Evaluation (INFCE, 1980) stated that it is feasible to markedly reduce the enrichment of a great majority of research reactors and endorsed the conversion of HEU-fueled research reactors to lower enrichment.

In 1977, the United States announced a nuclear nonproliferation initiative to significantly reduce U.S.-supplied inventories of HEU and announced plans for a research program to develop low enriched (20% U-235 or less) alternative fuels. The Reduced Enrichment Research and Test Reactor (RERTR) Program has been successful in developing low enriched fuels suitable for virtually all of the world's research reactors.

In 1981, Representative Ed Markey (D-Massachusetts) introduced an amendment to the NRC Authorization Bill to ban HEU exports altogether. The amendment was rejected because most Members were persuaded that the United States would phase out HEU exports as soon as new fuels became available through the RERTR program.

Foreign recipients of U.S. HEU generally have been supportive of the conversion program but also want assurance that the United States will stop using HEU as well. At the last annual international meeting in Japan of those concerned with the conversion program, the issue of "even handedness" by the United States was raised at a roundtable discussion. NRC Commissioner Victor Gilinsky told the meeting that the NRC "intends to demonstrate that conversion to low enriched fuel is not a difficult process by taking steps to enable domestic reactors operating in the United States to convert to low enriched fuels," and he cited the NRC's proposed rulemaking on HEU-use. Foreign reactor operators and their governments are waiting, however, to see whether the U.S. conversion actually is put into effect and how extensive it will be.

In August of 1982 the NRC issued a policy statement (47 FR 3006-3007) strongly supporting the RERTR program and announcing its interest "in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors." The statement concluded with this key paragraph:

> The commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. reactor operators.

Operators of NRC-licensed research reactors, however, recommended that the policy apply only to new reactors and to new fuel purchases. This approach at first received considerable support from the NRC staff, which recommended that the Commission adopt a limited conversion rule.

The problem with such a rule was that it would affect only the few larger reactors that require regular reloadings of HEU fuel. Most research reactors have a lifetime supply on hand. No new reactors are likely to be built any time soon. The NRC policy statement would have been gutted.

On January 27, the Commission heard from a panel of experts assembled by Nuclear Control as well as from nuclear-weapons, safeguards and proliferation specialists from a number of Federal agencies. The Commissioners' primary concern was that a comprehensive rule would incur an unacceptable financial burden on the universities. Many of the universities claimed that the costs of conversion would force them to shut down the reactors unless monetary aid was forthcoming.

On July 6, the Commission issued a proposed rule requiring the conversion of all research reactors under its jurisdiction, assuming the availability of financial support to cover the costs of conversion. Congress then appropriated $2 million toward the first-year costs of conversion. Exceptions can be made for larger reactors for which LEU fuel is not yet available or for reactors the Commission finds have a "unique purpose" necessitating continued use of HEU.

The cost of university reactor conversion (estimates range from $5 to $15 million) amounts to only 10 to 25 % of the total to be spent on developing the new fuels. In addition to the 24 HEU-fueled university research reactors, there are one government and four corporate HEU-fueled reactors, licensed by the NRC.

The Reagan Administration and HEU

A strong final NRC rule can set an important example with regard to converting research reactors at home and abroad, but the ultimate success of a conversion policy depends on the actions of the Reagan Administration. Although the RERTR Program has been largely successful, it has received less than enthusiastic support from certain quarters within the Department of Energy (DOE), the lead agency for the program.

The GAO, in its 1982 report, found that in 1981 the program's funding had been reduced to a fraction of what it had been the year before. Since that time funding has been gradually increased, but it has taken three years to reach levels set by the previous Administration. Even now there are signs of a continuing struggle by proponents of the program to gain adequate funding.

DOE's operation of its own research reactors is a key HEU policy area. Although fewer in number than the NRC-licensed research reactors, the civilian DOE reactors account for 90 percent of the annual domestic civilian consumption of HEU. DOE is using one reactor (the Oak Ridge Reactor in Tennessee) to test fuels for RERTR but it has made no commitment as to converting the others. Foreign purchasers of U.S.-HEU fuel would most like to see the high power DOE reactors convert at the same time they convert their reactors. If the DOE reactors are not converted, foreign reactor operators may simply seek out non-U.S. suppliers of HEU and the conversion effort could collapse.

Ultimately, a successful U.S. effort to achieve an international ban on HEU use depends upon the Department of State. Even a full-scale domestic conversion will have little affect abroad if State fails to follow through by making conversion of overseas reactors a high priority foreign policy goal. Unfortunately, Richard Kennedy, the U.S. Ambassador-at-large for non-proliferation, in a letter to NRC Chairman Nunzio Palladino commenting on NRC's HEU policy, indicated that the original weak rule proposed by NRC staff would be compatible with the State Department's objectives:

> The proposed rule for conversion of domestic research and test reactors calls for replacement of spent HEU fuel with low enriched fuel, "if such action would be technically feasible with existing fuel technology at the time of refueling, and unless the licensee shows that the unique purposes of the project could not be achieved without using HEU fuel," would be compatible with the criteria used for establishing conversion feasibility and schedules in cooperation with foreign reactor operators.

The statement suggests that the State Department is not prepared to seek conversion of low-power foreign reactors with lifetime supplies of U.S. HEU fuel and is even willing to allow exceptions for continued HEU exports.

In his letter to Palladino, Kennedy stated that NRC's domestic rule would have only a "marginal benefit" for the State

Department. This suggests State Department concern that the NRC might be taking a harder line against HEU use than the United States is seeking abroad.

A Problem That Can Be Solved

There are many technically complex and politically difficult issues to contend with in seeking to prevent the proliferation of nuclear weapons, but the use of highly enriched, weapons grade uranium as fuel for civilian research reactors stands out as one problem that can be solved with relative ease. In contrast to the seemingly insurmountable technological barriers to achieving effective controls on some sensitive nuclear materials and technologies, the RERTR Program provides a readily achievable solution. Although many U.S. non-proliferation initiatives meet with stiff resistance abroad, the U.S. objective of phasing out exports of HEU in conjunction with cooperative efforts to convert research reactors to low enriched fuel has been received surprisingly well by foreign reactor operators and their governments.

Considering the impressive progress made by the RERTR program in developing alternative low-enriched fuels, the political costs to U.S. foreign policy of pushing for a complete ban and moving toward a moratorium on exports should not be that great. Even high-power research reactors can be converted to low-enriched fuel if the operators and their governments become convinced that the reduction in performance characteristics is an acceptable price to pay for the greater security achieved. DOE should be prepared to set an example with regard to its own high power research reactors.

In addition, the State Department should be working to retrieve all the HEU at low-power foreign reactors that have lifetime supplies on hand. Some of these reactors would continue to use HEU for 20 years or more even with a ban on U.S. exports unless the fuel is returned for the low-enriched alternative. A strong NRC rule with respect to equivalent U.S. reactors would help the State Department to achieve the return of lifetime cores of HEU.

If HEU fuel is not essential for research and if no further production of HEU is required for the weapons stockpile or for naval propulsion fuel, as may well be the case, the basis would be established for suspending further production of HEU and even for blending down existing HEU stocks into low enriched uranium for use in civilian research and power programs.

Exports[a] of HEU From 1954 Through 1982

Country	HEU (kg)[b]	Contained U-235 (kg)[b]	% U-235 (average)
Argentina	94	59	63
Austria	9.8	7.3	75
Australia	10	9.2	90
Belgium	187	159	85
Bolivia	c	c	-
Brazil	7.7	7.2	93
Canada	1,861	1,724	93
Columbia	3.1	2.8	90
Czech.	c	c	-
Denmark	26	24	92
Finland	3.9	.77	20
France	6,268	4,655	74
W. Germany	9,990	6,611	66
Greece	6.6	6.1	93
IAEA	.31	.25	81
Ireland	c	c	-
Indonesia	.018	.13	72
India	.098	.081	83
Israel	19	17	90
Iran	5.5	5.2	93
Italy	382	307	80
Japan	1,995	946	47
Korea	30	18	62
Malaysia	c	c	-
Mexico	30	12	42
Netherlands	63	57	89
Norway	.01	.008	80
Pakistan	5.8	5.2	90
Philippines	3.3	3.1	93
Portugal	7.7	7.2	93
Romania	39	37	93
South Africa	33	30	92
Spain	9.4	8.3	88
Sweden	148	133	90
Switzerland	8.8	8.0	91
Taiwan	9.9	9.2	93
Thailand	5.3	4.8	90
Turkey	5.3	4.8	90
U. Kingdom	2,301	2,141	93

(Table continued on back)

Country	HEU (kg)[b]	Contained U-235 (kg)[b]	% U-235 (average)
Uruguay	c	c	-
Venezuela	.011	.009	82
Vietnam	.39	.08	21
Yugoslavia	17	5.9	35
Zaire	1.4	.28	20
Total	23,590	16,980	72

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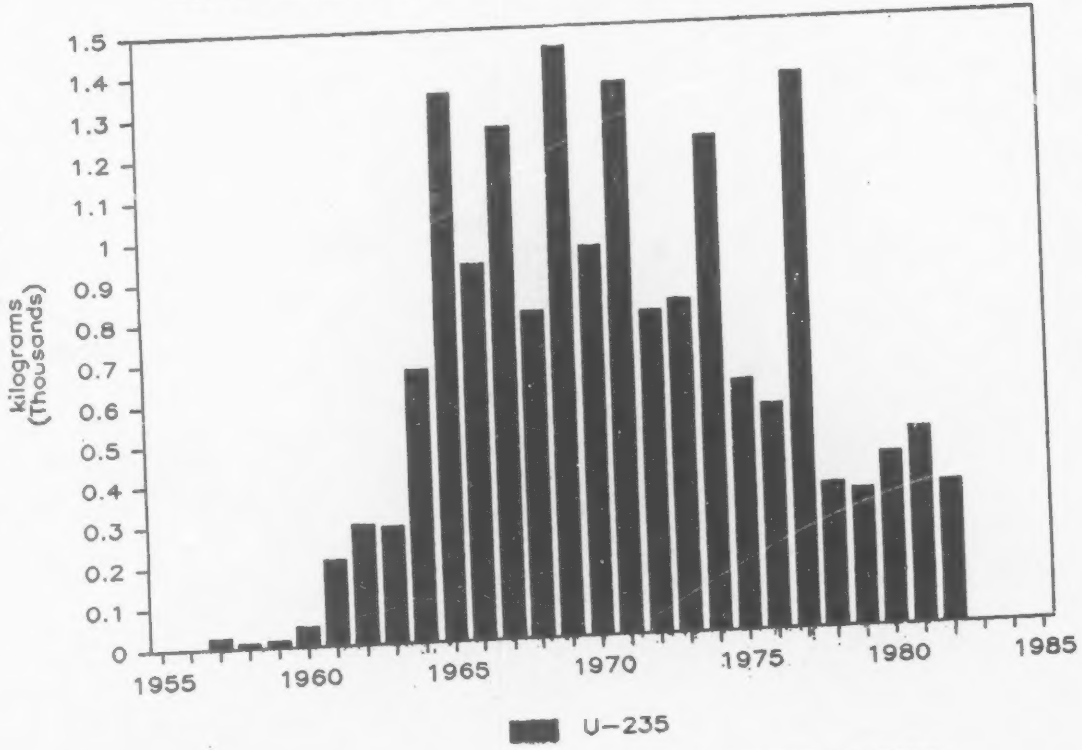
a. Figures represent shipments by U.S. to foreign countries. Returns to U.S. and retransfers to other foreign countries are not reflected in the data.
b. Amounts rounded off
c. A few grams at most.

Source: Department of Energy, Nuclear Materials Management and Safeguards System

Table prepared by David Albright, Federation of American Scientists

ANNUAL U.S. EXPORTS OF U-235



GRAPH PREPARED BY DAVID ALBRIGHT, FEDERATION OF AMERICAN SCIENTISTS

SOURCE: DEPT. OF ENERGY

September 25, 1984

Representative Fuqua
Chairman
Subcommittee on Energy Development and
Applications

Representative Lloyd
Chairman
Subcommittee on Energy Research and
Production
U.S. House of Representatives
Washington, D.C. 20515

Dear Chairmen Fuqua and Lloyd:

We are writing to object in the strongest terms the fact that your subcommittees have not invited to today's hearing representatives from public interest and scientific groups who have consistently supported the program to convert research and test reactors from highly enriched uranium to low enriched uranium fuels. Moreover, several of these groups have been actively involved in the formulation of the Nuclear Regulatory Commission's proposed rule requiring such conversion in NRC-licensed research and test reactors. We believe that in the interest of hearing both sides of this issue, you should schedule another hearing.

The need to convert research and test reactors to low enriched uranium fuel is clear. Conversion will protect against possible terrorist diversion, eliminate the need for and the expense of more security at universities, and set an example encouraging other nations to convert their reactors that use highly enriched uranium fuels. The cost of conversion is large by the standards of universities, but relatively small by the standards of the Department of Energy, which under the Nuclear Regulatory Commission's proposed rule, is expected to pay for the bulk of the conversion costs.

Our groups have actively worked to reduce the use of nuclear weapons-usable uranium in all civilian reactors. We support the Nuclear Regulatory Commission's proposed rule and will submit detailed comments on it. We were involved in the NRC hearings held last winter before the proposed rule was issued. We subsequently worked within Congress to obtain funding for the conversion of the NRC licensed research reactors. In addition, the Federation of American Scientists testified this summer in West Germany on the proliferation risk posed by a possible increase in the amount of highly enriched uranium to be stored at the Nukem uranium fuel fabrication plant in West Germany.

We appreciate the committees' consideration of our views and urge you to schedule an additional hearing before your subcommittees take any action or make any recommendations with regard to the NRC conversion rule.

Sincerely,

David Albright

David Albright
Federation of American
Scientists

Paul Leventhal
Nuclear Control
Institute

Dan Hersch

Dan Hersch
Committee to Bridge
the Gap

Thomas B. Cochran
Natural Resources
Defense Council

Michael Faden
Union of Concerned Scientists

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DAVID S. JEFFERY
Minority Staff Director

September 27, 1984

Mr. David Albright
Federation of American Scientists
307 Massachusetts Ave, N.E.
Washington, D.C. 20002

Dear Mr. Albright:

Thank you for your letter of September 25, 1984, concerning the conversion of research reactors from highly enriched to low enriched uranium fuel. We would be pleased to receive your views in written form to include in the record of the proceedings of our September 25 hearing, and will hold the record open until October 15, 1984 for that purpose.

Currently there are no plans for further hearings on this subject.

Sincerely,

Marilyn Lloyd

DON FUQUA
Chairman, Subcommittee on
Energy Development and
Applications

MARILYN LLOYD
Chairman, Subcommittee on
Energy Research and
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Minority Staff Director

September 27, 1984

Mr. Paul Leventhal
Nuclear Control Institute
1000 Connecticut Ave., N.W.
Washington, D.C. 20036

Dear Mr. Leventhal:

Thank you for your letter of September 25, 1984, concerning the conversion of research reactors from highly enriched to low enriched uranium fuel. We would be pleased to receive your views in written form to include in the record of the proceedings of our September 25 hearing, and will hold the record open until October 15, 1984 for that purpose.

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Sincerely,

Don Fuqua
DON FUQUA
Chairman, Subcommittee on
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Marilyn Lloyd
MARILYN LLOYD
Chairman, Subcommittee on
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Minority Staff Director

September 27, 1984

Mr. Dan Hersch
Committee to Bridge the Gap
1637 Butler Avenue, No. 203
Los Angeles, California 90025

Dear Mr. Hersch:

Thank you for your letter of September 25, 1984, concerning the conversion of research reactors from highly enriched to low enriched uranium fuel. We would be pleased to receive your views in written form to include in the record of the proceedings of our September 25 hearing, and will hold the record open until October 15, 1984 for that purpose.

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Sincerely,

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Minority Staff Director

September 27, 1984

Mr. Thomas B. Cochran
Natural Resources Defense Council
1725 I Street, N.W.
Washington, D.C. 20006

Dear Mr. Cochran:

Thank you for your letter of September 25, 1984, concerning the conversion of research reactors from highly enriched to low enriched uranium fuel. We would be pleased to receive your views in written form to include in the record of the proceedings of our September 25 hearing, and will hold the record open until October 15, 1984 for that purpose.

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DAVID S. JEFFERY
Minority Staff Director

October 1, 1984

Mr. Michael Faden
Union of Concerned Scientists
1346 Connecticut Ave., N.W.
Washington, D.C. 20036

Dear Mr. Faden:

Thank you for your letter of September 25, 1984, concerning the conversion of research reactors from highly enriched to low enriched uranium fuel. We would be pleased to receive your views in written form to include in the record of the proceedings of our September 25 hearing, and will hold the record open until October 15, 1984 for that purpose.

Currently there are no plans for further hearings on this subject.

Sincerely,

DON FUQUA
Chairman, Subcommittee on
Energy Development and
Applications

MARILYN LLOYD
Chairman, Subcommittee on
Energy Research and
Production

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
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October 12, 1984

STATEMENT OF STEVEN AFTERGOOD
Executive Director, Committee to Bridge the Gap

Before the
Subcommittee on Energy Development and Applications
and the
Subcommittee on Energy Research and Production
Committee on Science and Technology
U.S. House of Representatives

ON THE NEED TO CONVERT DOMESTIC AND FOREIGN RESEARCH AND TEST REACTORS TO LOW-ENRICHED URANIUM FUEL

My name is Steven Aftergood. My professional background is in engineering and solid state physics. I am presently executive director of the Committee to Bridge the Gap, a 15 year old non-profit research organization, focusing on technical and policy aspects of nuclear reactor safety, and on questions of nuclear nonproliferation.

We strongly favor the proposal of the Nuclear Regulatory Commission to minimize as far as possible the use of highly enriched uranium (HEU) in domestic research reactors. The HEU found at some 30 NRC-licensed facilities around the country is perhaps the most attractive potential source of illicit weapons-grade materials anywhere, due to the relative ease with which it can be used, even in very small quantities, to make a nuclear weapon. The decrepit state of security precautions at many of these facilities may make them the most vulnerable targets as well. Obstacles to conversion have been overstated: The NRC has made provision for exemptions in the few cases where national research interests might be compromised. The public supports conversion, and will not intervene to block it. Indeed, as discussed below, it is those facilities which do not convert that will face significantly increased financial burdens, and the prospect of legal intervention and public hearings. In conformity with national interests and bipartisan nonproliferation policies, the NRC proposed rule should be commended and implemented.

Background

In the 1950s and 1960s, low power research reactors were built around the world which utilized fuel containing 20% or less enriched uranium. This value was chosen because it was considered to be a limit for weapons usable material.(1) Highly enriched uranium (HEU) came into demand for high power research reactors, and eventually many low power reactors for which Low Enriched Uranium (LEU) would have sufficed were using HEU instead.(2) In the 1970s, however, particularly after India exploded a nuclear weapon using nuclear material obtained through a research reactor, concern grew once again about the use of HEU in research reactors.

It became national policy to attempt to reduce the proliferation threat posed by HEU, in part by trying to reduce the amount of HEU in use throughout the world, particularly for research reactors. This led to the establishment of the RERTR (Reduced Enrichment Research and Test Reactor) Program in 1978 to develop suitable LEU replacement fuels for research reactors.

As stated by the Hon. Charles N. Van Doren, Assistant Director, Bureau of Non-Proliferation, U.S. Arms Control and Disarmament Agency:

> ...In April of 1977, the President announced plans to minimize HEU uses by requiring, among other things, a careful economic and technical justification for its use, by minimizing HEU inventories, and by seeking to convert existing research reactors to the use of lower enrichments as quickly as possible.(3)

This policy was acclaimed and accepted internationally. According to then-Acting Under Secretary C. Worthington Bateman of the Dept. of Energy:

> ...I would like to mention the reduced enrichment research and test reactor program. The objective of this program is to develop and demonstrate technology that can use low-enriched uranium fuels in research reactors now using HEU fuel. This is a move which has been supported by INFCE /International Fuel Cycle Evaluation of the International Atomic Energy Agency/ and NASAP /Nonproliferation Alternative Systems Assessment Program/. Foreign acceptance of this program is also widespread. ... This is something we are committed to.(4)

The Hon. John M. Deutch, Director of Energy Research, Dept. of Energy, explained the need to convert U.S. reactors which use HEU:

> ...In the first place it will be necessary to convert our U.S. domestic research reactors. There are two reasons for this. First, to show that it is possible to convert research reactors and to set an example for other nations of the world. Second, to establish the required experience which will be needed to guide our further efforts.(5)

Thus, it has been the well-considered and established national policy to reduce the risks of proliferation by reducing the use of HEU, with prompt conversion of domestic reactors to serve as the basis for similar international policy, by setting an example for other countries and by acquiring the necessary expertise in carrying out such conversions.

Since its inception, this policy has been embraced and affirmed by the Nuclear Regulatory Commission, which awaited only the availability of suitable replacement fuels to require conversion. As stated in its 1982 policy statement:

> The Nuclear Regulatory Commission ... is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors.(6)

Further:

> The objectives of the RERTR program have been fully supported by NRC since its inception. ... The Commission is pleased to note that the current [i.e., Reagan] Administration continues to support the RERTR program and that Congress has approved adequate funding for the program.(7)

The Commission noted a lack of enthusiasm on the part of NRC licensees, but declared an overriding interest in conversion:

> The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. research reactor operators.(8)

HEU Reactor Fuel is Ideal for Use in a Weapon

HEU is a proliferation threat because it is weapons-grade. That is, it can be used in a nuclear explosive device. Of course, the uranium itself must be chemically extracted from the fuel matrix. But this is a surprisingly simple undertaking, which anyone with an undergraduate chemistry background and a few hundred dollars worth of equipment could perform. Methods for extraction of uranium are widely understood; a crude but effective method has even been published in the *New Yorker* magazine.(9)

While extraction from irradiated fuel is more difficult, due to the presence of radioactive fission products, it is still a relatively simple matter, especially since most domestic research reactors are operated at low power and therefore not highly radioactive. Methods for reprocessing of irradiated fuel are likewise widely published, and easily available at most university engineering libraries.(10)

Furthermore, HEU can be of strategic significance in extremely small quantities. While the fast critical mass required for an explosive device with a thick beryllium reflector is 11 kilograms at normal density, this modest amount can be dramatically reduced by imploding the device and increasing the density of the uranium. In fact, the fast critical mass is reduced by the square of the implosion factor, and such a device can be imploded and the uranium density increased by "several times"(11) using conventional explosives. Thus, if the density of the uranium and reflector is increased by a factor of two, only $\frac{1}{4}$ of the normal critical mass is required. If the density is increased by a factor of three, only 1/9 of critical mass at normal density is required!(12)

Thus kilogram quantities of HEU must be considered a potential threat to international stability. It would be a gross error to assume that several reactor inventories would have to be diverted to pose a serious threat. The HEU supply at virtually any one reactor which uses HEU is a potential threat in and of itself. In light of the relative ease with which HEU can be purified and the potency of even very small quantities, these reactor fuels may be the most attractive potential source of weapons grade materials to someone intent on constructing a nuclear explosive device.

Security at Nonpower Reactors Is Inadequate to Protect Strategic Materials

Compounding the threat posed by the attractiveness of HEU is the typically shocking state of security at many nonpower reactor facilities.

Most nonpower reactors which use HEU fuels are located at university and college campuses. In the nature of things, universities cannot provide the level of security found at government, military, or even most industrial facilities. Certainly they could not do so without endangering the open atmosphere of an academic environment, and without compromising their putative purpose, namely education and research. Relatively speaking, U.S. campus reactors are probably the most vulnerable targets in the world to a would-be terrorist bent on acquiring weapons-grade materials. This fact is not altered by the security measures prescribed by the NRC.

In fact, the NRC Staff and many licensees have claimed that no protection against theft whatsoever is required by law, but only post-theft detection and reporting. In the words of an NRC Staff attorney in the UCLA reactor relicensing proceeding:

> ... nonpower reactors ... are not required to protect against sabotage or theft. They are simply required to detect unauthorized access to violators.(13)

This shocking revelation of NRC procedure leads to an obvious question, posed by a Licensing Board judge:

> Is it a violation if a person gets in, gets the fuel, gets detected and gets away with it?

And the NRC Staff response:

> No, as long as the licensee has the proper system, whether it be in the form of a person or persons, or alarms, as long as the licensee is capable and does detect an unauthorized intrusion.(14)

The irresponsible character of this position takes it well beyond the absurd.

Given such a "standard" of security, one shudders to think of what the actual level of security is. And indeed, even the minimal precautions required by the NRC are routinely violated, as is indicated by a review of NRC security inspection reports. A survey of an incredible variety of such violations has recently been presented to the NRC Commissioners.(15) To cite just a few of many dozens of examples:

> One research reactor, built twenty years ago when the campus wished to make the reactor a campus "showplace," was built with virtually all walls and doors made out of glass so that people passing by could see directly into the reactor room. Inspectors years later expressed concern about this from a security point of view, since glass walls do not provide much barrier to penetration!
>
> At another facility, an inspector found that when the alarm system was armed and he walked around the reactor room for a considerable period of time, he was unable to set off the alarm.
>
> Similarly, an inspector found a reactor security system to have been plagued with false alarms, so the licensee had "tuned down" the alarm sensitivity to a level that made it impossible to detect intrusion.
>
> One inspection report cites the requirement that "key locks should provide a high degree of resistance to opening by force or tamper techniques.... The inspector demonstrated to licensee staff that the door ... could be opened using a small screwdriver."
>
> In several cases, keys had been given out to people who later left the institution without the keys being retrieved or the facility rekeyed.

At the recently shutdown UCLA reactor, several kilograms of fresh (unirradiated) HEU fuel were for many years stored in merely an ordinary filing cabinet with a lock. We have been informed by the NRC Director of Safeguards that as late as this year, this practice has persisted at at least some facilities and is not prohibited by federal regulations. A sworn declaration by physicist Dr. Theodore B. Taylor giving his view of this appalling practice is attached. Because the fresh fuel at UCLA has now been removed, we are only now releasing this hitherto confidential document.

In short, the level of security at most nonpower reactors is, even under the best, NRC-approved conditions, grossly inadequate for the protection of strategic nuclear materials. It would be a relatively simple matter for terrorists (or reactor employees) to steal or divert such materials.

Adequate security precautions, including armed guards, metal detectors, and effective restrictions on access would be unacceptable at most academic institutions and would, in any case, severely restrict the educational and research functions of the affected reactors. And perhaps most compelling of all, the financial costs of such measures over an extended period of time would be many times the cost of conversion to LEU, which would at the same time eliminate the need for them.

Conversion to LEU Will Not Restrict U.S. Research Capabilities

Those who are opposed to the reduction in use of HEU argue that conversion to LEU will weaken or destroy a vital national resource--the research and training capabilities provided by the reactors which use HEU. These reactors, it is claimed, will be prevented from carrying out certain experiments which require HEU, or will shutdown rather than convert to LEU for financial reasons. This is false.

The Department of Energy's RERTR Program will have devoted roughly $50 million to develop LEU replacement fuels for most reactors which will enable them to function with negligible if any adverse impact on performance. In most cases, the reactors after conversion will be able to carry out all research and education of which they were capable prior to conversion.

In any case, the NRC's proposed rule has explicitly provided an exemption from conversion for any reactor licensee who can demonstrate that its HEU fuel serves a unique purpose which cannot be fulfilled using LEU. Thus there is no way that conversion will hamper research capabilities.

The proposed rule further presumes that the financial costs of conversion to LEU will be borne by the federal government, so that there will be no inordinate economic burden on the licensees which might induce them to shutdown rather than convert. As stated in the NRC's Regulatory Analysis of the rule, "The implementation provision of the proposed rule attempts to minimize the financial, functional, administrative and licensing costs of the conversion process."(16)

In fact, the relaxation of security requirements accompanying conversion to LEU (instead of their future intensification at licensee expense) will enhance the educational function of these reactors, as well as saving money for the licensee. The same NRC document states:

> For most reactors, conversion from HEU to LEU fuel would permit a facility to employ a lower classification of safeguards requirements. This lower classification could lead to a small savings in safeguards costs based on existing requirements. The savings, however, would be further increased after implementation of additional safeguards measures being pursued by /_NRC_/ staff.... In addition to this cost savings, an argument can be made that the educational value of university facilities is enhanced as the requirements imposed by safeguards regulations are removed.(17)

Whereas the costs of conversion will be paid by the government, minimizing the burden on licensees, increased costs due to an imminent upgrade in security to protect weapons-grade materials would have to be paid by the licensees. Thus, it is not conversion but retention of HEU which will financially impact reactor licensees. Further, non-conversion will likely lead to a number of reactor shutdowns due to inability to afford necessarily upgraded security requirements for HEU.

It is inevitable that several nonpower reactors will shut down, whether or not the NRC rule is implemented. Student interest in nuclear engineering programs has steadily declined, reactors which used to produce medical radioisotopes have been replaced in some instances with accelerators designed specifically for this purpose. More fundamentally, many of these facilities are two decades old or more, and their research applications have long since been exhausted. They have lived out their operational lifetime. Independently of the proposed rule, some eight or ten research reactors (most of which used LEU) have closed down over the last several years, citing plummeting student enrollments and curtailed usefulness of their aging devices.

However, as mentioned above, it is retention of HEU rather than conversion which will place greater stress on these facilities. This is due not only to the various financial and institutional effects of increased security requirements. In addition, facilities which use HEU are encountering ever greater local opposition to HEU use.

This will inevitably increase if these reactors do not convert, as discussed below.

In remarkable contrast to the public statements of organizational representatives, reactor operators have privately expressed willingness to convert to LEU, provided only that costs of conversion be covered by the government, and that the licensees be shielded from unduly burdensome licensing requirements. In a detailed survey of all HEU-fueled academic institutions, Dr. G.L. Pollack of Michigan State University summarized his conclusions as follows:

> The reactor administrators are generally in favor of the conversions to LEU and would be cooperative. ... Now would be a good time to move rapidly on converting university reactors to LEU since: (a) the reactor people are generally in favor, (b) NRC and DOE are seriously interested, and (c) most of the technical problems are solved or seem to be near solution.(18)

Now is the time to begin converting these reactors.

In summary, the proposed NRC rule is designed to protect national research interests by exempting reactors whose performance would be restricted due to conversion, and by minimizing the financial burden on those which do convert. And in reality, conversion will be a bargain compared to the increased security-related expenses which remaining HEU facilities will have to pay.

Those Reactors Which Convert Will NOT Be More Vulnerable to Litigation

Several opponents of conversion have claimed before this Committee that conversion should not be required because it will lead to costly and burdensome litigation by members of the public challenging any license amendment. One speaker warned of "the loss of still further research reactors due to the near-certain exposure to unmanageable costs of litigation." Another asserted that "there are anti-nuclear groups waiting to 'pounce' upon any public notice [of license amendment]..." and to instigate litigation. In fact, just the opposite is the case. Conversion will reduce the potential for litigation, and make research reactors easier to license and relicense. It is those facilities which continue to use HEU which will face legal challenges.

In the past several years, there have been literally hundreds of amendments to operating licenses. They are routinely published in the Federal Register. There has never been a single public challenge to a license amendment. There have been four challenges to licensing or relicensing of nonpower reactors of which I am aware. Of these, two dealt with the use of HEU fuel. In each case, the challengers favored conversion.

The organization with which I work, the Committee to Bridge the Gap, has been the intervenor challenging the relicensing of the recently shutdown UCLA research reactor. Having been involved in this proceeding for five years, we are by far the most experienced public group concerned with the legal and technical issues of nonpower reactor safety. Concerned individuals and organizations around the country have frequently turned to us for information or advice on nonpower reactors in their communities. We know personally many of the active groups in many of these communities.

We can therefore state with confidence that legal intervention to block conversion to LEU is extremely unlikely. All such organizations, like a vast majority of the informed public, favor the elimination of HEU wherever possible and would never seek to obstruct the conversion process. Conversion to LEU would strongly reduce the basis for public concern, and hence the likelihood of legal challenges. We can further state unequivocally that our organization would not engage in any such intervention, nor would we assist others to do so.

On the other hand, any reactors which continue to use HEU will almost inevitably face strongly increased public pressure. Those facilities which are due to be relicensed in coming years will likely face legal interventions; any others will certainly encounter demands for conversion from their local communities, their institutions, state Legislatures, and the media, as well as the possibility of legal action on any future amendment, and a range of other legal and public challenges. Given the international security implications of HEU use, and the easy availability of an alternative in the form of LEU, we suspect that there would be a rash of legal and other challenges to nonpower reactors, with broad and active support from many sectors of the American public.

Thus once again, it is not conversion, but non-conversion which may threaten the viability of many nonpower reactors.

The Example of UCLA Should Encourage Conversion

The UCLA reactor relicensing proceeding, which recently led to the shutdown of the reactor after several years of litigation and much expense, has been cited as an example of the "danger" of litigation which licensees will face if they convert to LEU. As explained above, those licensees which convert will not be subject to litigation. But the assumptions inherent in the claim concerning UCLA are false, and should be exposed.

First of all, it should be understood that the UCLA case involved an application for full-scale operating license renewal, not merely a limited license amendment, as would be required for conversion to LEU. In an operating license renewal, an enormous variety of issues are raised by reactor operation and are therefore potential subjects for litigation, at least in principle. With regard to a license amendment, on the other hand, only the narrowest of matters relevant to the subject of the amendment can be raised by a challenger. Therefore, with regard to LEU conversions, no litigation on the scale of the UCLA case is even possible.

In any case, the UCLA reactor was shut down, not because of the burden of litigation, but because its application for operating license renewal would likely have been denied, to the embarrassment of the University. The lengthy evidentiary record in the case revealed a reactor facility with an extraordinary history of safety violations, mismanagement, and potential for major accident involving fuel melting and radioactive contamination. As mentioned above, HEU fuel had been stored in a filing cabinet. Hinges were located on the outside of doors, where they could be disassembled and the door easily removed! The alarm system was on occasion found to be unable to detect intrusion. And on and on.

These latter security concerns would of course have been reduced or eliminated had UCLA used LEU instead of weapons-grade HEU. But even the safety concerns would have been mitigated with LEU fuel. This is because LEU is generally more resistant to fire, with a higher melting temperature, and has increased resistance to the sort of destructive power excursion to which the UCLA reactor was vulnerable. The UCLA reactor would have been safer with LEU, as well as easier to license.

But it used HEU. And even the NRC's Atomic Safety and Licensing Board had to condemn UCLA's "sloppiness" and to term their defense "superficial." They warned that on one key safety issue, "there is not much in the record to support UCLA." The University was even found to have made false statements about reactor security to the NRC judges. So defeat was practically inevitable.

For the purposes of this Committee, the question of security for the UCLA reactor's HEU is most germane. Three former U.S. intelligence officers, including a former FBI special-agent-in-charge, and a former deputy director of the CIA, offered testimony or sworn statements that the presence of HEU was undesirable at UCLA, and that security was totally inadequate to protect the weapons-grade fuel. In camera hearings were scheduled at which a variety of scenarios would be elucidated, by which security could be penetrated, alarms bypassed, and fuel stolen.

Unable to meet its burden, however, UCLA acted to withdraw from the proceeding one week prior to these hearings.

The exemplary value of the UCLA reactor case lies not so much in its history of litigation, but in the fact that the reactor would have been much easier to license if it had been fueled with LEU. Use of LEU would not only have eliminated almost all security concerns, but would have yielded a safer reactor as well.

Here too the lesson is that conversion is in the interests of licensees. Those licensees which convert to LEU will be spared a repetition of the UCLA experience. But those which continue to use HEU may not be.

Conclusions

The HEU fuel used in nonpower reactors must be considered uniquely attractive to would-be terrorists. For someone intent on constructing a clandestine nuclear explosive device, this fuel is the best source of weapons-grade material around. From a security viewpoint, the nonpower reactors are the most vulnerable to attack.

The NRC's proposed rule has been carefully crafted to avoid undue strain on reactor licensees. The obstacles to conversion have been exaggerated or misstated. The public favors conversion and will not interfere in the license amendment procedure. Conversion will not restrict legitimate research activities requiring HEU, for which the possibility of an exemption has been allowed.

Refusal to convert will mean an increased financial burden on licensees to cover upgraded security requirements, and increased pressure from the public, including the possibility of litigation.

Conversion from HEU to LEU is consistent with national interests and established policies. The NRC rule should be promptly implemented.

# # #

NOTES

(1) See IAEA-TECDOC-233, "Research Reactor Core Conversion from the Use of Highly Enriched Uranium to the Use of Low Enriched Uranium Fuels Guidebook," a Technical Document issued by the International Atomic Energy Agency, Vienna, 1980, page 1.

(2) Ibid.

(3) Statement of Hon. Charles N. Van Doren, before the Subcommittees on International Security and Scientific Affairs and on International Economic Policy and Trade of the Committee on Foreign Affairs, U.S. House of Representatives, Ninety Sixth Congress, March 12, 1979, page 26

(4) Statement of C. Worthington Bateman, Acting Under Secretary, Department of Energy, before the Subcommittees on International Security and Scientific Affairs and on International Economic Policy and Trade of the Committee on Foreign Affairs, U.S. House of Representatives, Ninety Sixth, April 16, 1980, page 4

(5) Statement of Hon. John M. Deutch, Director of Energy Research, Department of Energy, before the Subcommittee on International Security and Scientific Affairs and on International Economic Policy and Trade of the Committee on Foreign Affairs, U.S. House of Representatives, Ninety Sixth Congress, March 12, 1979, page 7

(6) "Use of HEU in Research Reactors; Policy Statement," August 24, 1982, 47 Federal Register 37007

(7) ibid.

(8) ibid., 37008

(9) reprinted in John McPhee, The Curve of Binding Energy, Random House, New York, 1973, page 97

(10) see, for example, "The Processing of Uranium-Aluminum Reactor Fuel Elements," by F.L. Culler, Jr., and F.R. Bruce, in Proceedings of the Geneva Conference on Peaceful Uses of Atomic Energy

(11) John S. Foster, "Nuclear Weapons," Encyclopedia Americana, 1970

(12) For more information on the utilization and strategic significance of kilogram quantities of HEU, and the consequent need to convert domestic research reactors to LEU, see the Statement of Dr. Theodore B. Taylor, before the Nuclear Regulatory Commission Regarding the Need to Convert Domestic Research Reactors from HEU to LEU Fuels, January 27, 1984

(13) Pre-hearing Conference in the Matter of the Regents of the University of California (UCLA Research Reactor), February 5, 1981, transcript page 395

(14) ibid., page 396-7

(15) "Weapons-Grade Uranium on Campus: A Report to the NRC Commissioners," by Daniel Hirsch, Director, Stevenson Program on Nuclear Policy, University of California, Santa Cruz, CA 95064, January 27, 1984, page 21-24

(16) Regulatory Analysis of Limiting the Use of High-Enriched Uranium (HEU) in Domestic Non-Power Reactors, page 5, attached to SECY 84-211, Nuclear Regulatory Commission, May 22, 1984

(17) ibid., pp. 10-11

(18) Memorandum from Gerald L. Pollack to NRC Commissioner Gilinsky on Converting Reactors at Academic Institutions from HEU to LEU, September 22, 1983, page 1,3

Attachment A

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of THE REGENTS OF THE UNIVERSITY OF CALIFORNIA (UCLA Research Reactor)	Docket No. 50-142 (Proposed Renewal of Facility License)

SUPPLEMENTARY DECLARATION OF DR. THEODORE B. TAYLOR

I, Theodore B. Taylor, declare as follows:

1. I have read the attached minutes of the May 22, 1973, meeting of the UCLA Radiation Use Committee.

2. If it is true, as indicated therein, that a new fuel loading for the UCLA reactor was being kept in filing cabinets, first in the control room and thereafter in the radioactive materials storage room, I would find such a situation shocking.

3. It would be irresponsible on the part of the authorities to permit storage of weapons-grade materials, particularly in kilogram quantities, in filing cabinets. The fact that the cabinets may be locked, or even, though not indicated in the minutes, that the storage room might be alarmed, in no way mitigates the necessity of better protection for highly enriched uranium than an item of basic office furniture, which is readily portable on a dolly and poses no real resistance to entry. There is no excuse for not storing highly enriched material like that in a heavy monolithic container which is very difficult to move or penetrate and which, even under normal circumstances, takes considerable time to enter, preferably requiring more than one person to do so.

4. If UCLA has indeed, as the attached minutes indicate, stored a new fuel loading for its reactor, or for that matter kilogram quantities of highly enriched uranium, in filing cabinets, such a practice would, in my view, be grossly inadequate and indicate to me a serious failure to comprehend the significance of that material and the potential serious consequences that could arise from its theft. This would provide further basis for my concern that UCLA's application for nearly five kilograms of weapons-grade uranium not be granted.

I declare under penalty of perjury that the above is true and correct to the best of my knowledge and belief.

Theodore B Taylor

Theodore B. Taylor

Executed at Damascas, Maryland, this 16 day of December, 1982

Professional Qualifications

DR. THEODORE B. TAYLOR

My name is Theodore B. Taylor. I am Chairman of the Board of Nova, Inc., a technical consulting firm specializing in energy applications.

I received my B.S. degree in physics in 1945 from the California Institute of Technology and my Ph.D. degree in theoretical physics from Cornell University in 1954.

From 1946 to 1949 I worked as a theoretical physicist at the University of California Radiation Laboratory in Berkeley.

From 1949 to 1956 I was on the staff of the Los Alamos Scientific Laboratory, working on the design of nuclear explosives. One of my primary assignments at Los Alamos was to design fission bombs of very small physical dimensions and mass.

In 1956 I joined the General Atomic Division of General Dynamics Corporation where, along with Edward Teller, Freeman Dyson, and others, I helped design the TRIGA research reactor. While at General Atomic I was also technical director of the Nuclear Space Propulsion Project (Project Orion).

From 1964 to 1966 I was deputy director (scientific) of the Defense Atomic Support Agency, U.S. Department of Defense.

I spent the following two years in Vienna, Austria, as an independent consultant to the U.S. Atomic Energy Commission and several other organizations, working on the subject of international safeguards for nuclear materials.

In 1967 I founded the International Research and Technology Corporation, a company primarily concerned with studies of the impact of technology on society, which I served as Chairman of the Board until 1976.

From 1976 to 1980 I was Visiting Lecturer with rank of Professor in the Mechanical and Aerospace Engineering Department at Princeton University.

In the aftermath of the accident at the Three Mile Island nuclear power plant, I served as a Commissioner on the President's Commission on the Accident at Three Mile Island (the "Kemeny Commission.")

I am a member of the American Association for the Advancement of Science and the American Physical Society, a member

of the Board of Directors of Nuclear Control Institute, and have served as a consultant to the Air Force Science Advisory Board, 1955-58, Los Alamos Scientific Laboratory, 1956-64, Aerospace Corporation, 1960-61, Atomic Energy Commission, 1966-70, Defense Atomic Support Agency, 1966-69, Rockefeller Foundation 1977-79, and was chairman of the Los Alamos Study Group, Air Force Space Study Commission, 1961.

In 1965 I was one of the recipients of the Ernest C. Lawrence Memorial Award of the AEC for work on the development of nuclear explosives and the TRIGA research reactor.

I am co-author of The Restoration of The Earth (1973),Nuclear Theft: Risks and Safeguards (1974), Energy: The Next Twenty Years (1979), and author of numerous articles on nuclear safeguards and proliferation in technical journals and popular media. A more detailed account of my activities in the safeguards field can be found in John McPhee's book, The Curve of Binding Energy (1973, 1974).

I maintain an active "Q" clearance.

University of California
Los Angeles, CA.

Energy and Kinetics Dept.

RADIATION USE COMMITTEE

Minutes of the Meeting of May 22, 1973

Members Present: Hicks, Okrent, Erdmann, Catton, Brower, Hornor

Members Absent: Kastenberg

Dr. Hicks stated that the meeting was being held to discuss transferring the location of the unirradiated fuel loading.

At the present time we are storing a new fuel loading for the reactor in the reactor control room in locked file cabinets. Due to the sensitive nature of this material, it is felt that the security of the fuel would be greatly enhanced if the storage cabinets were moved to the radioactive storage room. A problem arises in that Section III, Part E, of the UCLA Training Reactor Hazards Analysis, states that the storage cabinets will be kept in the control room. 10 CFR 50.59 allows us to make a change in the facility as described in the hazards analysis, provided that the change does not constitute a change in technical specifications incorporated in the license or an unreviewed safety question. The technical specifications incorporated in the license simply state that the fuel will be stored and handled in a geometry, such that K_{eff} is less than 0.8 under optimum conditions of moderation and reflection. This criteria has already been met in that the fuel bundles are being kept in locked storage cabinets which are lined with cadmium. The purpose of the committee meeting is to determine whether or not the proposed change as to the storage location for the fuel constitutes an unreviewed safety question.

The committee discussed the change and unanimously agreed that the moving of the fuel from the control room to radioactive storage does not constitute an unreviewed safety question.

Dr. Hicks suggested that a letter should be sent to the Berkeley operations office describing the change, and all members agreed.

The meeting was then adjourned.

Testimony Submitted For the Record of the September 25 Proceedings of the Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production

On the Conversion of Domestic Civilian Research and Test Reactors to Low Enriched Uranium Fuel

by David Albright
Federation of American Scientists
Washington, D.C.
October 15, 1984

Before I begin, I would like to thank the chairmen for holding open the record of the September 25 proceedings on the Nuclear Regulatory Commission's proposed rule for the conversion of the NRC licensed research and test reactors from highly enriched uranium (HEU) to low enriched uranium fuels (LEU). I hope, as I and several others expressed in our letter to the subcommittees, that an additional hearing on this subject will eventually be held. I still believe that it would be useful to hear a broader range of views about the need to convert research reactors to LEU fuels.

I would like to discuss several reasons why the NRC's proposed rule should be adapted in its present form and should be viewed as a beginning of the eventual conversion of all reactors in the United States that use HEU fuels. My comments reflect my work at the Federation of American Scientists (FAS) on the technical issues associated with nuclear proliferation. This testimony represents my own views and does not necessarily represent the views of FAS.

Background

Highly enriched uranium can be used to make nuclear explosives. Its widespread use in fuel in reactors increases the risks of proliferation through theft or diversion of the HEU. A single theft of HEU by an irresponsible government or a terrorist group could have profound consequences. It could be used to extort concessions from a government or to construct an explosive if enough is stolen. Furthermore, the theft could be perpetrated in any country. The irresponsible government or terrorist group might steal the HEU from the most responsible nation.

Currently, about 45 civilian research and test reactors in the United States and about 90 in foreign countries use HEU supplied by the United States. Each year these reactors need roughly 1100 kilograms of HEU, which requires that about four times this amount of HEU be in circulation in transport, in fuel fabrication plants, at the reactors, or at reprocessing plants (Travelli, 1983). The total amount in circulation represents, using conservative estimates, over 150 nuclear weapons equivalents. About 90 percent of the yearly civilian HEU requirements in the United States is used in the DOE civilian reactors. About half of the total annual U.S. requirement of HEU is used in one reactor, the DOE's Advanced Test Reactor at the Idaho National Engineering Laboratory.

Highly enriched uranium is also used in high temperature reactors. In the United States it is used in the commercial high temperature gas reactor at Fort St. Vrain in Colorado. And in West Germany the thorium high temperature reactor (THTR) that is nearing operation will use HEU fuel. Each year the West German reactor will require about 170 kilograms of HEU (NF, 1984). The Fort St. Vrain reactor is roughly estimated to need about 220 kilograms of HEU per year (NEI, 1982).

United States policy has attempted to reduce the use of HEU in foreign research reactors. To this end, the reduced enrichment for research and test reactors (RERTR) program was established in 1978 by the Department of Energy. It has been developing and demonstrating new types of LEU fuels that can replace the HEU fuels without significantly affecting reactor performance or fuel cycle costs of most research reactors.

In 1982 the NRC issued a policy statement which stated that the NRC "is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors (Federal Register, 1982)." The NRC's proposed rule has resulted from this policy statement.

Because the Fort St. Vrain reactor is a power reactor, it is not included in the NRC's proposed rule. In regard to the West German THTR, which is also not considered a research reactor, Nuclear Fuel reported that the Department of Defense is concerned about the United States supplying HEU to the West German reactor in the absence of any firm plans by the reactor owners to convert it to LEU fuels (NF, 1984). According to Nuclear Fuel, the Defense Department's concern was apparently prompted when the NRC postponed its decision on an export license to supply this reactor with additional HEU until the State Department decides whether the United States is prepared to commit itself to supplying HEU each year for the lifetime of the reactor (NF, 1984).

Concerning the DOE reactors, Dr. Kane, Deputy Director, Office of Energy Research, DOE, stated at the hearing held September 25, that any decision to convert DOE reactors is several years away, although few of the DOE reactors are presently expected to convert. Instead, he added, security at the reactors might be upgraded.

Reasons For Implementing the NRC's Proposed Rule

Congress should support the implementation of the NRC's proposed rule for the following reasons:

1. It would help reduce the future threat of terrorism within the United States by reducing the amount of HEU in circulation.

   While at present NRC licensed research reactors do not seem to be a likely target of terrorist groups, it is clear from past acts by international terrorist groups, as NRC Commissioner Bernthal noted, "that a threat can materialize without sufficent warning from intelligence sources."

Because the amount of HEU potentially affected by the NRC's proposed rule is only a relatively small part of the total amount used in the United States, Congress should not lose sight of the need to enlarge the number of reactors that will convert to LEU fuels. Congress can begin with the DOE civilian research reactors presently using HEU fuel and with a study on the feasibility of converting the high temperature reactor at Ft. St. Vrain to less enriched uranium fuels.

2. Conversion to LEU fuels would eliminate the need for any increased physical protection of the HEU fuels.

In the case of the university reactors, present levels of security are inadequate not only to protect the unirradiated HEU, but also, in several cases, the irradiated HEU, which in these cases is not sufficently self-protecting to prevent its diversion (Hersch, 1984). The necessary increase in the physical protection of the HEU would be very expensive and these costs would most likely come out of the universities' budgets.

More generally, the constraints imposed on the university programs by the physical protection of HEU interfere with research activities and are incompatible with an open university environment.

3. Conversion of the NRC-licensed research and test reactors could very well reduce the threat of interventions at future relicensing hearings.

Reactor owners have often stated that conversion to LEU fuels might require a license amendment which would have a public hearing with the opportunity for public intervention. The owners fear that the public hearings would result in several research reactors being closed down.

· While such fears cannot be dismissed lightly, the likelihood of such an intervention on a licensing amendment rather than a licensing renewal is rather remote. In fact, intervention might be less of a threat in the case of conversion, because so many groups on all sides of the nuclear debate support converting reactors to LEU fuels. These groups have a vested interest in seeing that the conversion process is successful.

By avoiding converting to LEU fuels, research reactor owners might actually create an environment favoring interventions. Groups might decide to intervene because they are concerned about the proliferation risks of HEU regardless of the level of physical protection of the HEU fuels.

4. The NRC's proposed rule would help alleviate the frequently expressed concern of the foreign reactor owners that a "double standard may be applied in deciding the acceptability of using HEU in foreign and U.S. research reactors (GAO, 1882, p. 51)." While it is impossible to predict whether this type of concern by foreign reactor owners would undermine foreign conversion, it is in the interest of both the NRC and the DOE to require conversion of reactors under their authority in order to create the best possible precedent overseas.

At the fifth annual RERTR meeting in Japan during the fall of 1983, a U.S. government participant at the meeting noted that the likelihood of NRC-licensed reactors being required to convert was good news to the participants at the conference.

However, in comments on the NRC's proposed rule, Peter von der Hardt, director of the Petten research reactor in the Netherlands, stated that since the rule does not cover the large DOE research reactors, the example set by the conversion of the NRC licensed reactors is weakened.

Dr. von der Hardt's comment is a further argument for the conversion of more of the U.S. reactors that use HEU fuels. Rather than using his comment as a justification to weaken the NRC's proposed rule, as some of the research reactor owners have done, Congress should use it to justify a program that would enlarge the numbers of reactors that convert from HEU to LEU fuels.

5. Besides setting an example, the implementation of the NRC's proposed rule would lead to the development of valuable licensing and technical information. The NRC plans to share this information with the overseas reactor owners and this sharing will contribute to a more efficient and economical conversion process overseas.

Conclusion

The NRC proposed rule is a sound rule that warrants the support of Congress. For this rule to be successful, however, Congress must continue to adequately fund DOE'S RERTR program and plan to pay all the conversion costs.

The conversion of the NRC-licensed reactors should be viewed as only a first step in eventually eliminating the use of HEU in reactors within the United States. It is a natural first step, however, since most of the NRC-licensed reactors are fairly small and relatively easy to convert compared to the other reactors. Congress should begin planning to convert all possible civilian reactors that use HEU fuels to the new LEU fuels as they become available.

References

Federal Register, 1982: "Use of High-Enriched Uranium in Research Reactors; A Policy Statement," NRC, Federal Register, vol. 47, no. 164, August 24, 1982, p. 37007.

GAO, 1982, "Obstacles to U.S. Ability to Control and Track Weapons-Grade Uranium Supplied Abroad," General Accounting Office, GAO/ID-82-21, August 2, 1982.

Hersch, 1984: Testimony by Daniel Hersch, Committee to Bridge the Gap, before the NRC, January 27, 1984.

NEI, 1982: Nuclear Engineering International, August Supplement, 1982. This journal lists the uranium fuel inventory or the Fort St. Vrain reactor as 870 kilograms. The uranium is enriched to over 90 percent uranium-235. The annual HEU requirement stated in the testimony was derived by assuming that one quarter of the uranium fuel is reloaded each year (see A.V. Nero, Guidebook to Nuclear Reactors, University of California Press, 1979, p. 126).

NF, 1984: "HEU Shipment to West Germany Raises Concern of U.S. DOD," Nuclear Fuel, September 10, 1984, p. 2-3.

Travelli, 1983: "RERTR Program Activities Related to the Development and Application of New LEU Fuels," A. Travelli, Argonne National Laboratory, presented at the International Symposium on the Use and Development of Low and Medium Flux Reactors, MIT, October 17-19, 1983.

October 12, 1984

Statement of RONALD BAKAL, Esq.
Before
The Subcommittee on Energy Research and Production
and
The Subcommittee on Energy Development and Applications
of the
House Committee on Science and Technology

My name is Ronald Bakal. I am an attorney and a member of the Nuclear Law Center, a group of public interest attorneys who assist public groups in nuclear cases. We have been deeply involved in matters in which a public group challenged the adequacy of security at a local research reactor because it possessed weapons-grade nuclear materials with grossly inadequate security.

I understand the NRC has proposed a new regulation which would require research reactors to convert from weapons-grade fuels to low enriched, non-weapons-grade material. The rule has two purposes: to provide protection against the unique risks associated with potential theft of material from which a nuclear bomb could be manufactured, and to remove a major obstacle to completing a long-standing foreign policy objective of converting foreign research reactors from highly enriched uranium (HEU) and reducing the amount of such weapons materials that are internationally available for theft or diversion to weapons purposes.

Despite the fact that conversion seems to be a relatively quick and simple matter-- DOE simply retrieving the HEU fuel it has loaned these reactors and substituting LEU replacement fuel-- and despite the fact that it appears Congress is to pick up the tab involved, and has already appropriated a substantial portion of it, there remains some residual opposition among the potentially affected licensees. Some of the arguments appear particularly irrational, as the one that requiring conversion to LEU will cause public outcry and legal interventions against the research reactors. Exactly the opposite is the case.

UCLA, a reactor with HEU fuel, closed down permanently and withdrew its renewal application a week before it was to go to hearing on the serious inadequacies in its security. Intervenors wanted it to convert to LEU; it resisted. As in all cases to date, Intervenors have opposed the presence of HEU and urged replacement with LEU; it has never been the other way around.

Reactors with HEU fuel cannot meet their burdens in demonstrating sufficient security to protect against theft of weapons-grade materials. If reactor operators have legal concerns, conversion is the best answer for them, because the security needs go down, as well as public concern.

Of the hundreds of license amendments for research reactors, there has never been an Intervenor, even in matters far more controversial than conversion and where the change was clearly in the unsafe direction (e.g., an order of magnitude increase in power) as opposed to the clear reduction in risks involved with removing weapons-grade fuels from campuses. No interventions can be expected to occur in license amendment cases for HEU conversion, but they can be virtually guaranteed if these reactors do not convert and keep bomb-grade materials on site. This is the single most aggravating issue to public groups concerned with research reactors in their neighborhoods, and failure to convert can be expected to result, particularly in light of the UCLA case, in a flurry of legal actions and other public opposition to continued presence of weapons-grade material in their communities.

UCLA withdrew its application for renewal of its full license in large measure because it had weapons-grade uranium on site and inadequate security. Research reactor operators who wish to avoid the same public outcry should not stand in the way of conversion to LEU; if the conversion rule is overturned, it will likely result in precisely the kind of opposition to their facilities they say they so desire to avoid.

Conversion from weapons-grade fuels is really in the best interests of all parties. Public groups want bomb materials out of their neighborhoods. Reactor operators want reduced security problems and reduced risk of public opposition. And we all want, don't we, reduced risks that a terrorist group or state might acquire a clandestine nuclear weapon. Clear-sighted perception of the issue would indicate that it is in everyone's interests to remove weapons-usable materials from underprotected locations here and abroad.

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Representative Don Fuqua
Chairman
Subcommittee on Energy Development
and Applications
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Representative Marilyn Lloyd
Chairman
Subcommittee on Energy Research and
Production
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Representatives Fuqua and Lloyd:

The University of California's Student Body Presidents' Council, which represents the 141,000 students of the nine-campus University of California system, is appalled that your two subcommittees would conduct such an undemocratic public hearing as you did on September 25, 1984. Your two subcommittees held on that date a joint public hearing to consider the proposed regulation by the Nuclear Regulatory Commission on the Conversion of all research reactors which presently use highly enriched uranium (HEU) to the use of low enriched uranium (LEU). HEU is weapons-grade uranium and can with only slight modification and minimal technological expertise be used to build a nuclear bomb. LEU, with under 20% enrichment, cannot be readily used in the construction of a nuclear weapon. The Student Body Presidents' Council has unanimously endorsed the rule proposed by the NRC to require immediate and complete conversion. See the attached resolution.

SBPC has registered our official support for the conversion rule with the NRC. We were therefore outraged that your two subcommittees held a public hearing on the rule and allowed only public opponents of the rule such as nuclear reactor operators to present oral testimony. After reading their testimony, it does not seem possible for your two subcommittees to make a sufficiently informed recommendation to the NRC on the conversion rule, since you have heard only one side of that complex issue.

We are informed by your staff that, although we would not be permitted to provide oral testimony, we could submit written testimony after the hearing, which is attached. We request that you include this letter and the attached written statement and resolution in the official hearing record. We hope that in the future your subcommittees will be more conscious of including all points of view in your oral public hearings.

Sincerely,
Kevin Gillis
Kevin Gillis
Chair
Social Responsibility Committee

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STUDENT BODY PRESIDENTS' COUNCIL

STATEMENT OF

KEVIN GILLIS
STUDENT BODY PRESIDENTS' COUNCIL
UNIVERSITY OF CALIFORNIA

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
AND
ENERGY RESEARCH AND PRODUCTION SUBCOMMITTEE
U.S. HOUSE OF REPRESENTATIVES

October 10, 1984

My name is Kevin Gillis. I am the Chair of the Social Responsibility Committee of the University of California Student Body Presidents' Council, which represents the 141,000 students of the nine-campus University of California system. SBPC, because of its concern about the security and proliferation risks associated with the presence of weapons-grade uranium at university campuses, has unanimoisly endorsed the NRC proposal to replace highly enriched uranium (HEU) at these research reactors with low enriched uranium (LEU) from which atomic weapons could not be made if the material were stolen. We believe this is a very important positive step, and any attempt to reverse the proposed conversion of these reactors could have very serious results.

The potential security threat involved with having weapons-grade nuclear materials on university campuses is grave. As students who live and work on university campuses, we know that this highly sensitive material cannot be adequately protected by the small, untrained security "forses" on such campuses. The security which does exist at these facilities is often more extensive than the security found at the campus bookstore. Unlike nuclear power reactors,

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which are located in sparsely populated areas with extensive security, such as large exclusion zones, security perimeters and containment structures, these nuclear research reactors are located on densely populated college campuses, often surrounded by large urban centers. Reactors sit on these campuses without any security of the security precautoins found associated with power reactors. Students and visitors move freely around the normal classroom buildings in which the reactors are housed. Since the reactors are used for instruction and students on work-study are employed in the reactor fecilities, any registered student can gain access and even possession of the keys to the facilities in which weapon-grade uranium is stored. As students ourselves, know that these student employees do not always realize or understand the sensitivity of the material with which they are working.

This low level security is unacceptable for material which, if stolen, could result in a major national or international crisis. This lax security must be improved if HEU is to remain on college campuses. However, the cost of improving security to an adequate level could be far too expensive for the Universitiee. It appears as if the reactor operators have claimed that conversion is too expensive and if requirred to convert, they will have to close down their facilities. However, considering the cost of technological alarms and security systems, and the employment of armed guards at the site, the cost of providing sufficient security could well be far more expensive than the actual conversion to non-weapon grade material, which is the most comprehensive security fix. The Department of Energy has agreed to help with the cost of conversion. No government agency will subsidize security. Therefore,

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it simply makes no sense to channel funding from educational programs to expensive security, considering its already tight budget.

Many of the operators have argued against the conversion rule and have said that no terrorist attacks have as of yet been reported against the research reactors. However, no one can deny that terrorism is an unfortunate reality in our modern world. In the past no bombs ever exploded at American embassies or at our nations capitol. However, today this type of terrorism occurs and we students do not want the terrorist target to remain on our college campuses in the future. Must we await a successful theft of HEU from a campus before action is taken. As Turinsky indicated in his testimony to your subcommittees, there has been a rapid decline in student enrollment in the nuclear engineering programs nationwide. For instance, in the University of California system, there are four nuclear research reactors; two of which are fueled by HEU, UCLA and UCSanta Barbara. A systemwide engineering review committee in 1982 reported that the four nuclear engineering departments should be consulidated due to the very low student enrollment. There can be no justification for continuing to permit weapons grade uranium to remain in use at reactors which have such diminished educational benefit when replacement fuel is available. The topic before these two subcommittees is the proposed rule of conversion from HEU to LEU fuel. The only acedemic question is whether such a conversion will interfer with the research potential of the reactors. According to our investigations with our faculty, the research potential will not be hamped to any significant degree. Very few experiments would have to be alterêd in the least and those exceptions would be altered only slightly. The important consideration is the actual health and safety problems passed by the HEU.

The dangers of having weapons grade uranium on college campuses is being seen by both campus student organizations and governments and community citizen organizations. Their combined public outcry has helped promot the NRC to propose the HEU conversion rule, Some of the individuals who have testified before the subcommittees orally said that public interventions will follow the passage of the HEU conversion rule, by the exact organizations who have supported its conception. This is a completely false representation of the students position. There has never been public action against action which was intended to improve the safety of nuclear reactors, which this conversion rule is clearly an example. There have been several interventions when public safety was endangered. The Universities need not fear intervention if they comply with the HEU conversion. However, there will almost assuredly be a rash of interventions nad lengthly litigation if the NRC does not pass this regulation and if individual universities do not comply in removing weapons materials from campuses.

Again the students of the University of California which has two HEU fueled reactors are appalled at the dangerous and negligant security at these sensitive facilities. Due to the cost of improving security the universities should take steps to decrease the potentiality of a terrorist theft by converting to non-weapons grade uranium. This conversion will not effect the acedemic potential of the education and the research at these facilities. Lastly, the universities need not fear intervention or litigation if they improve the safety of the reactors by conversion. However, intervention and litigation of public opposition is sure to follow if the reactors do not convert. The presence of weapons-grade uranium at open universities would be a continuing source of public contraversy and concern, as well as a major security risk, that can best be alleviated by the proposed NRC rule. Were weapons-grade uranium ever stolen from a university reactor, the consequences could be devastating. Conversion to non-bomb grade fuel is the best protection available against that catastrophic potentiality.

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RESOLUTION

Supporting the Proposed Rule by the Nuclear Regulatory Commission on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

WHEREAS, 31 non-power nuclear reactors are licensed in the United States to use highly enriched uranium (HEU)- 25 are owned by universities including one at UCLA and one at UC Santa Barbara, 5 are owned by private corporations and 1 is owned by the U.S. government; and

WHEREAS, highly enriched uranium can be used without further significant processing and without extensive expertise to build nuclear weapons; and

WHEREAS, the security level at these facilities especially at those on university campuses are not sufficient to even moderately protect from a threat of theft; and

WHEREAS, the threat of terrorism is rapidly escalating world-wide and HEU could sell for over $100,000 per kilogram on the black market; and

WHEREAS, the United States government has spoken out around the world for the reduction of HEU, while at the same time the U.S. exports about 600 kilograms annually (the most in the world) and has not made an effort to limit the almost 500 kilograms of HEU within the U.S.; and

WHEREAS, the reduction of HEU within the U.S. may provide an example and incentive for other nations to emulate thus reducing the danger of international terrorism; and

WHEREAS, the low enriched uranium (LEU) fuels can be used without significant reduction in performance or research potential; now, therefore, be it

RESOLVED, that the Student Body Presidents' Council supports immediate conversion from HEU to LEU internationally and especially within the United States and that the rule must allow no exemptions if it is to accomplish its goal of enhancing national and international security.

8/18/84
KJG

October 10, 1984

STATEMENT OF DR. DAVID W. HAFEMEISTER

Subcommittee on Energy Development and Applications, and
Subcommittee on Energy Research and Production,
Committee on Science and Technology
House of Representatives

REGUARDING THE NEED TO CONVERT DOMESTIC RESEARCH REACTORS FROM HIGHLY ENRICHED TO LOW-ENRICHED URNAIUM FUELS

BIOGRAPHY BRIEF

I am a Professor of Physics at the California Polytechnic University. My curriculum vitae is attached. From 1962 to 1966, I used research reactors at the University of Illinois and at the Los Alamos Scientific Laboratory to carry out experiments in nuclear and solid state physics. From 1975 to 1977, I was Science Advisor to Senator John Glenn, who was the Ad-Hoc Chairman of the Governmental Affairs Committee on Nonproliferation matters. From 1977-79 I was Special Assistant and Expert Consultant to Under Secretary of State Lucy Benson and Deputy Under Secretary Joseph Nye, working primarily on nonproliferation matters. Among other responsibilities, I was the lead State Department delegate to Working Group 8 (Advanced Fuel Cycle and Reactor Concepts) of the International Fuel Cycle Evaluation (INFCE) which was held at the Internaional Atomic Energy Agency (IAEA) in Vienna. Subgroup C of this Working Group had as its sole task the assessment of methods of reducing proliferation risks associated with research reactors. I also was a member of the interagency Subgroup on Nuclear Exports (SNEC).

CONCLUSION

It is my opinion that research reactors in the U.S. should be required to convert from high-enriched uranium fuels (HEU) to low-enriched uranium fuels (LEU). The lower flux reactors can convert to the presently available uranium-aluminum fuels, and the higher flux reactors can convert to the uranium-silicon fuels which will be available in a few years. Exceptions to this conversion should be allowed only upon a finding that the new fuels would not be feasible. This conclusion is based on (1) requirements for adequate physical security, (2) consistency with the national policy on nonproliferation, and (3) technical availability of the new LEU fuels. If the NRC's proposed rule requiring conversion to non-weapons grade fuel does not go forward as planned, which I think would be a mistake, and HEU remained at these reactors, security would have to be strictly increased. The strictly increased security would be far more expensive than conversion, it would be academically intrusive, and it would be far less effective in reducing risks of theft of weapons-usable material. Failure to go forward with domestic conversion would throw a major obstical in the way of our long standing foreign policy goal of conversion of foreign reactors and reduction in the international commerce of HEU.

WEAPONS IMPLICATIONS

There is general agreement that highly-enriched uranium is dangerous in that nuclear weapons can be fabricated from this material. The proliferation risk associated with HEU is that it can be used directly to make nuclear weapons, unlike the low-enriched uranium used, for example, in power reactors. No further enrichment, generally very costly and difficult, would be necessary in order utilize the material in a clandestine fission explosive, thus making it a potentially attractive target for theft or diversion. For this and related reasons, it has been the policy, both nationally and internationlly, to attempt to minimze the amount of HEU in use.

The American Nuclear Society acknowledges this problem. In a recent study (C. Starr, Science 224, 952 (1984)), the American Nuclear Society stated that:

> "There are now about 350 research reactors in about 50 countries, of which 25 are developing countries. Many of these reactors are too small to produce signficant amounts of plutonium. However, most of them have been supplied with highly enriched uranium fuel, which, in principle, might be accumulated to make a single nuclear device. This possiblity is now being precluded by conversion to lower enrichment (less than 20 percent) designs."

HEU WEAPONS

Since HEU can be used directly to fashion a clandestine fission explosive by either a state or a terrorist group, the use of HEU should be minimized, and when HEU is used it must be under adequate physical security. LEU is considerably less effective as a nuclear explosion since (1) it requires about 15 times more LEU uranium than HEU uranium (with reflectors), (2) about 3 times more U-235, and (3) it is much more difficult to develop and deliver a nuclear weapon that consists of hundreds of kilograms of uranium.

HISTORICAL PERSPECTIVE

The Indian device of 1974 hightened concerns in the U.S., the Congress, and the Executive Branch. Shortly after this event, about one-half dozen contracts were signed to export enrichment and reprocessing plants to smaller nations, many of which did not have an economic need for such facilities. In response to these events, the Congress commissioned a study by the Office of Technology Assessment. The OTA report (1977) acknowledged that solutions to nuclear nonproliferation are not simple by stating that:

> "It is not too late to contain proliferation at a level which can be assimilated by the international political system. However, there are no single or all-purpose solutions; no short-cuts. A viable nonproliferation policy will require the coordinated, planned use of a wide variety of measures."

THE RESPONSE OF THE CONGRESS

The U.S. Congress (essentially unanimously) responded to this situation by passing the Nuclear Nonproliferation Act of 1978 (NNPA) and the Glenn-Symington Amendment. As a result of these and other actions, the U.S. policy is to minimize the use of HEU in the world. The U.S. government has not exported HEU for lower-flux reactors, and it has asked for conversion to higher density fuels in the future for higher-flux reactors. This program, known as the Reduced-Enrichment Research and Test Reactor Program (RERTR), represents the official policy of the United States aimed at attempting to reduce enrichments of research reactor fuels and thus the amount of HEU in use.

INTERNATIONAL RESPONSE

The summary report of the International Nuclear Fuel Cycle Evaluation (1980) has stated that it is feasible to markedly reduce the uranium enrichment of a great majority of research reactors: INFCE endorsed the conversion of HEU fueled research reactors to lower enrichment.

HEU EXPORT LICENSES

The U.S. no longer will accept new commitments to export HEU for foreign research reactors. New research reactors are being sold only with LEU fuels. A few commitments for HEU for high-flux research reactors are being carried out on an interim basis to Belgium, France, Holland and Japan, but, we have asked them to convert to LEU, and, as I understand it, they have agreed to do so. Recently, the U.S. did export 0.9 kg of HEU to the Canadian-built SLOW POKE reactor in Jamaica, but the Canadians have stated they will not request any more HEU for their research reactors.

HEU AND THE APPLICATION OF THE GLENN-SYMINGTON AMENDMENT

This amendment denies military and economic aid to those non-nuclear weapons states that (a) explode a nuclear device, or (b) build enrichment and reprocessing facilities outside of an international framework. On April 6, 1979, this sanction was applied to Pakistan since it was concluded that Pakistan was building an enrichment plant to produce weapons-grade uranium. This sanction was later removed because of the Soviet invasion of Afganistan. I was intimately involved with this amendment while working with Senator Glenn (joining him in the House-Senate Conference where the House accepted the Senate language), and while working in the State Department (debating its merits before the Deputy Secretary of State, at OMB meetings, writing testimony, etc.) This amendment was adopted without dissent in the Congress. The Congress was, and is, concerned about HEU.

HEU IN THE IRAQI REACTOR

This HEU-fueled research reactor was destroyed by Israel in 1981. France no longer will export HEU to Iraq, but they will export LEU to Iraq.

CONSISTENCY IN FOREIGN POLICY

The professional staffs concerned with nonproliferation matters are convinced that it would be helpful to convert U.S. research reactors in order to be consistent with the French, Canadian, and American positions. Interagency meetings at OMB might try to soften this position, but I know of no serious nonproliferation staff member who would disagree with the conversion requirement. As we have seen from the examples of Pakistan and Iraq, nonproliferation can be compromised by other foreign policy concerns. It is true that the carrying out of a sanction against one nation, may well cost us in our diplomatic standing with that nation, and that larger events (such as the Soviet invasion of Afganistan) can push nonproliferation policy the other way, towards ignoring the problem. The beauty of the HEU conversion proposal is that, for at most $15 million, the U.S. can achieve consistency between what we demand of others and what we demand of ourselves. I have found out from personal experience when dealing with nuclear officials of other nations that "moral leadership" quite often does not work in foreign policy, but most of us would agree that being inconsistent by favoring our university reactors with HEU will certainly make the political climate abroad for the HEU to LEU conversions all the more difficult. In the area of nonproliferation policy, the $15 million figure is relatively minor, as compared to other costs in this area.

INTERNATIONAL RAMIFICATIONS IF THE DOMESTIC RULE IS REVERSED

Domestic HEU conversion would be consistent with U.S. policy of protecting against the very worrisome prospect of large quantities of HEU without adequate safeguards. Failure to take this precaution in the U.S. would damage U.S. foreign policy interests by undercutting our government's attempts to reduce international commerce in HEU and convince other nations of the need to reduce their HEU holdings. I know from personal experience in representing the State Department in interactions with nuclear officials from other countries that it will be much more difficult for the U.S. to succeed in its policy of reduced enrichments and HEU holdings abroad if the policy is not vigoriously pursed at home. This inconsistency would not be lost on the nations we are trying to influence.

PHYSICAL SECURITY

It should be stated that it is both national and international policy that kilogram quantities of HEU must be safeguarded. While timely warning, after the fact, of theft or diversion is a key element in such safeguards, post-loss reporting is not sufficient protection and fails to minimize the possibliites for unauthorized removal os such material. The removal of kilogram quanities of 93% enriched U-235 would have extraordinarily serious potential consequences.

Section 10 CFR 73.67(a)(1) states that

> "Each licensee ... shall establish and maintain a physical proctection system that will achieve the following objectives:
>
> (i) Minimize the possibilites for unauthorized removal of special nuclear material consistent with the potential consequences of such actions: and
>
> (ii) Facilitate the location and recovery of missing special nuclear material."

First of all, I would like to address the word "consequences" in (i). The consequences of obtaining HEU could be the development of a nuclear device which could destabilize our international framework of nations. This extremely serious event might kill thousands of people and could be a precursor to an international conflict. Next I would like to address the word "consistent" in (i). To minimize the possibiliites of unauthorized removal in a way which is consistent with the seriousness of the potential consequences of such a removal means that very stringent physical security and recovery techniques must be available. The (hypothetical) intrusion must be site-specific. Is the facility really secure? The time line of possible recovery must be considered. How long would it take for a recovery team to arrive? Would the signal be triggered by the penetration into the building, and would there be time delays before the penetration of the secondary barriers? From where would recovery team come? Would the detection devices be applicable for fuel that was not very radioactive? How far can a vehicle travel during this time to get away with the fuel? What is scan rate of the aircraft? If it is 70 square kilometers per hour, then this would imply a radius of 4.7 km (3 miles). The minimum velocity of the escape vehicle would have to be

$$V\ (\mathrm{MPH}) = 3/T$$

where T is the arrival time in hours of the monitoring aircraft after the first signal. If it took one hour after detecting the first signal of the violation to obtain a scanning aircraft above the reactor, the minimum velocity of the vehicle would be 3 MPH. It is difficult to imagine any vehicle being slow enough to get caught under this circumstances. In other words, one cannot contain HEU with post-theft detection since the fuel would be gone.

RADIATION BARRIER

As I understand it, the radiation level of a bundle of fuel from a typical 100 kW reactor would drop to only about 10 REM/hour (unshielded at 3 feet) in about 7 days after shutdown. Since this level would not deter theft, it would be necessary to protect the HEU with strict physical security measures.

CONCLUSIONS

Research reactors in the U.S. should be required to convert from HEU to LEU. The lower-flux reactors should do this within the near term, and the higher-flux reactors should convert to LEU when the U-Si fuels are available. Exceptions should be permitted only for the very rare case where it can be shown that this conversion is infeasible. If the reactors are not converted to LEU, then the reactors should be operated so that the fuel bundles will have strict physical security to protect them. Our long standing efforts to reduce HEU would be severely damaged if the proposed rule did not go into effect.

David W. Hafemeister

Professional Qualifications

1. Education:
   - a. Bachelor of Science degree in Mechanical Engineering from Northwestern University, 1957
   - b. MS. and Ph.D. in Physics, University of Illinois, 1959, 1964
   - c. Post-Doctoral Fellowships:
     - Los Alamos Scientific Laboratory (1964-66)
     - American Association for the Advancement of Science Congressional Fellowship (1975-1976)

2. Employment
   - a. Mechanical Engineer, Argonne National Lab (1957-58)
   - b. Physicist, Los Alamos Scientific Laboratory (1964-66)
   - c. Assistant Professor of Physics, Carnegie-Mellow University (1966-69)
   - d. Associate Professor of Physics (1969-72)
     Professor of Physics (1972-)
     California Polytechnic University, San Luis Obispo, CA
   - e. Visiting Professor of Physics
     University of Groningen, The Netherlands (1972, 1980)
   - f. Legislative Assistant and Science Advisor to Senator John Glenn
     U.S. Senate (1975-77)
   - g. Special Assistant to Under Secretary of State Lucy Benson and Deputy-Under Secretary Joseph Nye, U.S. Department of State (1977-1979)
   - h. Visiting Scientist, Mass. Instit. of Technology (1983-4)

3. Experience with Nuclear Non-Proliferation Matters
   - a. U.S. Senate: After the detonation by India of a nuclear device in 1974, the Committee on Governmental Affairs of the U.S. Senate held extensive hearings on the "Export Reorganization Act of 1975" which dealt with nuclear nonproliferation. It was my job to be the full-time staffperson to the Ad-hoc Chairman of the Committee, Senator Glenn, on hearings and mark-up of the act. I was Senator Glenn's main advisor on nuclear non-proliferation matters.
   - b. Department of State: In 1977, I was appointed as one of two Special Assistant on the issue of nuclear nonproliferation to Under-Secretary Benson and Deputy-Under Secretary Nye. Dr. Nye had the lead role for nuclear non-proliferation in the Executive Branch and at the London Nuclear Supplier Negotiations.

     During this time, I was intimately involved with the drafting and passage of the Nuclear Non-Proliferation Act of 1978, participating in the Department of Energy's Non-proliferation Alternative Systems Assessment Program (NASAP), and dealing as a representative of the Under Secretary with officials of other nations' nuclear programs.

In addition, I was the lead State Department delegate to Working Group 8 (Advanced Fuel Cycle and Reactor Concepts) of the International Fuel Cycle Evaluation (INFCE) which was held at the International Atomic Energy Agency (IAEA) in Vienna. Subgroup C of this Working Group had as its sole task the assessment of methods of reducing proliferation risks associated with research reactors. DOS member of interagency Subgroup on Nuclear Exports (SNEC).

4. Publications

a. Nuclear Non-Proliferation:

i. "Nonproliferation and Alternative Nuclear Technologies", Technology Review 81, 58 (December 1978).

ii. "Science and Society Test V: Nuclear Nonproliferation", American Journal of Physics 48, 112 (1980)

iii. prime author/editor of the Presidential Report to the Congress on the environmental impacts associated with nuclear exports abroad (1980)

iv. co-author/editor of the Supplement Nuclear Research and Development Export Activities to ERDA 1542 (U.S. Nuclear Export Activities), September 1979.

b. Solid State and Nuclear Physics:

20 articles; four book chapters; one book

c. Energy Technology and Policy:

15 articles, co-edited 2 books

WEAPONS-GRADE URANIUM ON CAMPUS

The Need to Convert Research Reactors to Lower Enrichment Fuels

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WEAPONS-GRADE URANIUM ON CAMPUS

The Need to Convert Research Reactors to Lower Enrichment Fuels

The Unique Risk Associated With Non-Power Reactors

Of the security risks associated with research and test reactors--the necessity to protect against acts of radiological sabotage and, for those reactors utilizing highly enriched uranium as fuel, to protect also against theft of that material for use in construction of a clandestine fission explosive--the latter threat is essentially unique to this type of reactor. This is because many research and test reactors utilize uranium that is approximately thirty times more enriched than the fuel found at commercial power reactors. The uranium found at these largely university-based non-power reactors is, in fact, "weapons-grade"--directly useable, if stolen, for use in a nuclear weapon--and thus poses a significant proliferation hazard.

It has long been recognized that the primary substantive barrier to acquisition of a clandestine fission explosive is acquisition of the weapons-grade nuclear material; the design and construction techniques are neither secret nor terribly complicated. As nuclear weapons expert John S. Foster has written:

> "It must be appreciated that the only difficult part of making a fission bomb of some sort is the preparation of a supply of fissionable material of adequate purity; the design of the bomb itself is relatively easy..."[1]

Acquisition of weapons-grade materials has generally necessitated the use of reprocessing or enrichment facilities. A short-cut, however, is to divert or steal material already reprocessed or enriched, and that is why the highly enriched material found at many research reactors poses such an attractive target for those interested in acquiring a clandestine weapon.

"Gift-Wrapped Bomb Material"

Power reactors generally use fuel enriched to about 3% in the isotope uranium-235; Uranium of that enrichment cannot be used to make an atomic bomb. Many research reactors, however, use uranium enriched to abut 93%, directly useable in a nuclear weapon.

Furthermore, the form in which that uranium is found at these reactors--generally in flat plates alloyed with aluminum--is easily separated, providing little if any barrier to anyone who would have the requisite knowledge to make use of the uranium once separated. Extraction of the uranium is a Chem I effort, with widely published techniques and readily available equipment.

1/ formerly Director of the Lawrence Radiation Laboratory and Director of Defense Research and Engineering in the Department of Defense; quotation in Nuclear Theft: Risks and Safeguards, by Mason Willrich and Theodore Taylor, a Report to the Energy Policy Project of the Ford Foundation, Ballinger, Cambridge, Mass., 1974

Professor James Warf[2] has described two simple methods as follows:

> "Uranium and aluminum can be separated chemically from their eutectic by any number of techniques. One method is to dissolve the eutectic in hydrochloric acid, and oxidize the uranium to uranyl ion using nitric acid. Addition of excess sodium hydroxide precipitates the uranium as sodium diuranate, but converts the aluminum to the soluble aluminate ion. Separation is effected by centrifuging. Alternatively, the uranyl nitrate can be extrated by ether of butyle phosphate, leaving the aluminum in the aqueous phase."

Theodore Taylor has described[3] a method using even more accessible materials: putting the fuel in an aqueous solution of lye and fertilizer, after five hours adding barium nitrate, centrifuging for twenty minutes at 800 G's in a standard lab centrifuge. After pouring off the aluminum solution, you would have solid U-235.

Highly Enriched Uranium (HEU), particularly in the form of plate-type aluminum alloy fuel commonly found at university reactors, is thus an extremely attractive target for someone intent on acquiring a clandestine fission explosive, in part because of the low toxicity of uranium compared with plutonium, and in part because of the dual capability of uranium to be used in either a gun-type or implosion nuclear weapon.[4] Furthermore, because the fast critical mass goes down as the square of the implosion, quite small quantities of HEU are necessary for the latter type device.

Highly Enriched Uranium in the form of research reactor plate fuel must be seen as potential bomb material. The aluminum cladding and alloy are little more than gift-wrapping.

Security Problem Exacerbated by Unique Environment

The unique security problem thus associated with the use of bomb-grade materials by research reactors is exacerbated by the unique environment in which they are often located. Whereas power reactors are located behind large exclusion zones, security perimeters, and containment structures, often far from the nearest population center, many research reactors are located without any of these protections in the center of college campuses in the midst of highly populated urban areas. In particular, despite a major proliferation threat involved with potential theft or diversion of the weapons-grade materials on site, many of these reactors are located on university campuses where stringent security measures necessary to adequately protect such uniquely sensitive materials are perceived to conflict with the open atmosphere generally associated with such institutions.

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[2] Professor of Chemistry at USC and one of the founders of the Southern California Federation of Scientists; formerly Group Leader of analytical section and inorganic chemistry section of the Manhattan Project.

[3] in McPhee's The Curve of Binding Energy, Random House, New York, 1973,4

[4] The extraction of uranium from irradiated plate-type fuel has also been widely published. See, for example, "The Processing of Uranium-Aluminum Reactor Fuel Elements" by F.L. Culler, Jr. and F.R. Bruce from the 1956 Geneva Conference on Peaceful Uses of Atomic Energy.

As will be detailed below, security at these facilities is often extraordinarily lax. Weapons-grade nuclear materials, the theft of which could have very serious international implications, are generally provided a similar level of security on these campuses as personnel records or the student store. The principal and often solitary security precaution is a readily bypassed burglar alarm system set to alarm at the campus police offices. The weapons-grade materials are kept in ordinary classroom buildings in labs not dissimilar to any other lab. Oftentimes a score of students and staff have keys to the nuclear energy labs; when keys are lost or copied without authorization, rekeying of locks is often not done. Portions of the nuclear facilities' walls are often made of glass (one such facility is almost entirely surrounded by glass walls and doors) because they were intended as showplaces; thus physical barriers to unauthorized penetration are almost non-existent. As the reactors are designed as demonstration tools, thousands of visitors per year are brought through the facilities on tours with the kind of supervision (lax) normally found on campus tours. As the reactors are often largely run by students, the problems are magnified--doors left ajar or forgotten to be locked, keys left unattended, strangers permitted entry merely by knocking on back doors, and the like.

There is often a dangerous naivete at work with regards those assigned security responsibility at these campus reactors. One such individual--a former student who stayed on at the facility after graduating and serves in the dual capacity as reactor operator and security "officer"--remarked during the course of our investigation that one should not be concerned about security problems at research reactors like his because if someone stole the fuel, the FBI would, he asserted, eventually catch the thieves and even if not, "it's real hard to make a bomb." Similarly, in a letter to the LEU Study Group by the Senior Reactor Operator at another research reactor, the assertion that its essentially unirradiated HEU might pose proliferation risks if stolen is scoffed at because the uranium is clad with aluminum. Furthermore, students or staff at these facilities charged, in addition to other duties, with security are often quite unfamiliar with the NRC safeguards regulations. Some have even interpreted the regulations as requiring no preventive or protective measures whatsoever, but merely an ability to report the theft at some unspecified time (be it days or weeks) after it has occurred.

Thus, a unique security problem, with potentially very serious international implications, exists with regards many research reactors. Unlike power reactors, their fuel is at risk for theft or diversion by a group intent on acquiring a clandestine fission explosive; and unlike power reactors, they exist in environments where security precautions are strongly frowned upon as conflicting with an open atmosphere. On the one hand, they possess material that, if it fell into the wrong hands, could result in extraordinary danger; on the other hand, security measures orders of magnitude below that which power reactors (or even everyday commercial enterprises), possessing no such bomb-grade material, have in place.

A Two-Track Approach to the Problem

For a number of years, it has been the policy of the Nuclear Regulatory Commission and other federal and international agencies to pursue a two-track approach to the problem: upgrading the safeguards at facilities possessing weapons-grade materials and attempting to convert such facilities to use of lower enriched fuels that cannot be used directly to make an atomic bomb. The latter approach is based upon the fact that use of highly enriched fuels at most research reactors is totally unnecessary and a quirk of recent history--research reactors can, and have, done everything they need to do with Low Enriched Uranium (LEU) fuels, from which weapons cannot be directly made.

These two approaches--upgraded safeguards and conversion to non-weapons-grade fuels--have had wide acceptance internationally, in the Congress, and in the agencies of several administrations.

In April, 1977, the Administration announced a policy designed to reduce the threat of proliferation by attempting to reduce the risk of theft or diversion of HEU, in part by attempting to reduce the amount of HEU in use throughout the world, particularly for research reactors. As part of that policy, DOE began a program for Reduced Enrichment for Research and Test Reactors (RERTR), designed to develop advanced fuels for conversion of even the most high-powered research reactors. The Congress passed the Nuclear Nonproliferation Act of 1978 (virtually unanimously) recognizing many of these risks. And the International Nuclear Fuel Cycle Evaluation (1980) found the reduced enrichment program of conversion of research reactors to non-weapons-grade fuels among the few positive steps for non-proliferation about which there was wide agreement.

As the General Accounting Office found,[5]

> "The reduced enrichment program is one of the few concrete U.S. non-proliferation initiatives to gain widespread international support."

This non-proliferation initiative grew in part due to increased concern about proliferation after India exploded a nuclear weapon using nuclear technology and materials supplied by the West. Since the United States provides most of the HEU used by research reactors worldwide (other than those supplied by the USSR), reduction in HEU use worldwide became a high priority.

Barriers to U.S. Foreign Policy Goals of Foreign Conversion to LEU

Among the principal barriers to achieving the U.S. goal of conversion of foreign research reactors to non-weapons-grade fuels has been foreign perceptions about whether U.S. reactors will likewise be required to convert. As the GAO commented:

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[5] "Obstacles to U.S. Ability to Control and Track Weapons-Grade Uranium Supplied Abroad" GAO Report ID-82-21, August 2, 1982, Report by the Comptroller General to Senator Gary Hart

> "A number of issues complicate the acceptance of the new LEU fuel by foreign reactor operators. Frequently foreign operators perceive that a double standard may be applied in deciding the acceptability of using HEU in foreign and U.S. research reactors. For example, the U.S. Government has not indicated whether it will restrict or inhibit the continued use of HEU in U.S. reactors. . . . The lack of participation by U.S. facilities in converting to the new LEU fuel could undermine foreign acceptance of the new fuel and, thus, negate an important part of the U.S. non-proliferation objective. Of the 156 research reactors worldwide which use U.S. - supplied HEU enriched to between 70 and 94 percent in U-235, 54 (about one-third) are located in the United States."
>
> (emphasis added)

This dependence of achieving our foreign policy goal of LEU conversions abroad upon LEU conversions at home is widely recognized. As Dr. Herbert Scoville, President of the Arms Control Association and formerly Assistant Director of the U.S. Arms Control and Disarmament Agency and Deputy Director for Research of the Central Intelligence Agency, has said:

> "The move to cut down the amount of HEU at [domestic university reactors] can have very salutary international effects as well as ones locally. It is important from a U.S. policy standpoint to make as difficult as possible the acquisition of material such as HEU that can be easily fabricated into a bomb.
>
> "However, we cannot hope to have one standard in the U.S. for availability of HEU and for safeguards on its use and a different standard for other countries. The precedent set at [domestic university reactors] will be useful in dealing with other countries such as India or Brazil as they seek HEU for their research reactors."

Dr. Scoville continued:

> "A recent example of this problem arose in Iraq. The French were supplying Iraq with a research reactor using HEU. We tried to persuade the French to provide only lower enriched material but the Iraqi government refused to accept this. When the HEU became available in Baghdad the Israelis felt it necessary to carry out a preemptive bombing raid to destroy this reactor. While I think such a violent reaction was very ill-advised, it nevertheless demonstrates the dangers of having large amounts of HEU available in locations where it might be seized and converted to a weapons program. It is perhaps more likely that a nuclear war will start with a bomb being used by a small country or terrorist organization in the Middle East than that the Soviet Union and the United States will start a nuclear war with their thousands of warheads. Therefore the control of HEU is very important, and the standards set [in U.S. domestic research reactors] should be useful in dealing with such a problem in the future."

Thus, if our goals of reducing the threat of non-proliferation are to be achieved, conversion of foreign research reactors to LEU and concommitant reduction in commerce in weapons-grade materials are essential. And furthermore, conversion of foreign research reactors appears unlikely or impossible if domestic research reactors are exempted from this policy. Moreover, because of the small quantities of HEU necessary for an atomic bomb, particularly an implosion device, and because of the difficulties in providing adequate protection for such highly sensitive materials on open university campuses, conversion of domestic research reactors from use of weapons-grade uranium is likewise necessary to prevent the potential of theft or diversion of that material.

The Commission's Commitment to Conversion

Recognizing the unique proliferation risks associated with use of Highly Enriched Uranium, the objectives of the reduced enrichment program have been fully supported by the NRC since its inception. Recognizing the necessity of converting both foreign and domestic research reactors to LEU, and the barriers to conversion of the former if conversion of the latter is not likewise required, the Commission on August 17, 1982, issued a Statement of Policy on Use of High-Enriched Uranium (HEU) in Research Reactors.6/ Indicating in that Statement that it has licensing responsibility for domestic use and for export abroad of Special Nuclear Material, including High-Enriched Uranium, the Commission committed itself to

> "...reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors."
>
> (emphasis provided)

As the Commission stated in that Policy Statement:

> "In the mid 1970's, particularly following India's detonation of a nuclear explosive device in 1974, nuclear proliferation concerns began to increase. Expanded efforts were undertaken to prevent nuclear power programs from being exploited to produce nuclear weapons. Particular concerns were expressed with respect to proliferation risks associated with inventories of HEU for research and test reactors abroad. The widespread use of HEU fuel, which involved a large number of domestic and international fuel shipments, increases the risks of proliferation through theft or diversion of this material. In contrast to HEU, the use of fuel with lower enrichments reduces proliferation risks."

6/ 47 FR 37007

The Commission's Statement of Policy continued:

> "In an effort to allay concerns of proliferation risks, efforts were made to reduce HEU inventories, on the assumption that any reduction in the potential for access to these inventories would constitute a reduction in proliferation risks."

And it concluded:

> "The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. research reactor operators."7/

In short, the need to reduce use of weapons-grade uranium both at home and abroad has been widely accepted as a responsible and necessary policy. It is one of the few non-proliferation initiatives to have widespread support, in part because it is a sweet technical fix: research reactors can continue to do what they are doing now, but with fuel that doesn't pose a proliferation hazard if stolen or diverted. In fact, it is a very conservative policy--returning many reactors merely back to their original designs.

It is one of the ironies of this entire dilemma that it is largely an accident of history, perhaps a victim of short-sighted policies of the past. In the 1950s and 1960s, low power research reactors were built in many countries, including the U.S., which utilized fuel containing 20% or less enriched uranium, a value chosen because it was considered to be a limit for weapons usable material.8/ Highly enriched uranium came into demand for high power research reactors, and eventually many low power research reactors for which low enriched uranium would have sufficed were using HEU instead (sometimes even converted from LEU use). After the detonation of a nuclear device by India, concern over weapons-grade materials spread, and now research reactors are going back to low enriched fuels. It is one of the best indications of the lack of technical barriers to solving this problem that many of these reactors were originally designed to run on LEU; if they ran on it once, they can run on it again. Furthermore, reactors of different design can readily and without difficulty convert to LEU fuel, even fuel of different form than previously used. An interesting case is the University of Maryland which, some years ago, anticipating that the NRC would at some point require conversion to LEU, converted from HEU plate fuel to LEU TRIGA fuel.

Another interesting example is the University of Florida Argonaut-type reactor. The original Argonaut at Argonne National Labs used 20% oxide plate-type fuel. When the University of Florida Argonaut was built, it used metallic plate-type fuel, also 20%--expressly indicating it did so to minimize the need for security precautions.9/ It eventually converted to 90% enriched plate fuel, and is now in the process of converting once again, as part of a DOE demonstration project, this time to 4.8% LEU in the form of oxide rods. They report no major difficulties and view their experience as a prototype for other similar low-power research reactors.

7/ Commissioner Roberts added a footnote expressing concern about the steps not being specified.

8/ See IAEA-TECDOC-233, LEU Conversion Guidebook, Int'l. Atomic Energy Agency, 1980

9/ See 1958 Hazards Summary Report, University of Florida

Conversion of most research reactors is technically feasible now with current technology and is not difficult, involving primarily replacing HEU fuel with LEU; conversion of all but a very few high power research reactors will be readily done in the very near future with advanced fuels nearing final development by the RERTR program; and the Commission is pledged to a Policy of converting both domestic and foreign research reactors, "to the maximum extent possible." The maximum extent possible, in light of the lack of technical barriers, will represent a substantial reduction in the number of research reactors here and abroad using weapons-grade uranium.

Implementation of the Commission Policy on Conversion

After committing itself to converting, "to the maximum extent possible," domestic and foreign research reactors to non-weapons-useable fuels, the Commission began to solicit advice as to how to implement that formal Policy.

U.S. research reactor operators, who, as the Commission noted, "have shown little interest in converting to lower enrichment fuel," came forward with a proposal which essentially says that the Commission's Policy should be implemented by exempting all but a handful of domestic research reactors from the Policy.

The licensees' proposal, forwarded to the Commission by the Office of Policy Evaluation (OPE) after a meeting with industry representatives, made two recommendations which are somewhat deceptive in their simplicity. Their effect, however, is clear: if adopted, the Commission's August 1982 Policy would be gutted or overturned.

The two proposals are:[10]

- No new research reactors would be licensed to use HEU unless they could make a case they needed it.
- Existing research reactors when they replaced their cores would have to use LEU replacement fuel, unless they could make a case they needed HEU.

The recommendation paper, however, is quick to point out that the impacts of such an implementation procedure on the affected industry would be essentially non-existent because:

- No new research reactors are expected to be built in the foreseeable future, due in no small measure to the radical decline in enrollments in nuclear engineering programs. Research reactors are getting closed down for lack of use; no new domestic research reactors are expected to be built.
- The vast majority of research reactors, due to low burnup, would not replace their HEU cores. They would thus be exempted from the Policy of conversion.

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[10] transmitted by memo, Zerbe to Ahearne, March 1, 1983

It is clear that if the purpose of the Commission's Policy is to encourage conversion of foreign research reactors to non-weapons-grade fuel, the domestic industry's proposal of exempting all but 3-5 of U.S. research reactors from such conversion requirements is likely to strongly undercut our ability to persuade foreign operators to do something we are unwilling to require domestic operators to do. Likewise, if the Commission's Policy is, as stated, to reduce to the maximum extent possible amounts of HEU available, exempting 90% of domestic research reactors from such a Policy will gut it. If HEU use, as the Commission has said, "increases the risks of proliferation through theft or diversion of this material," and if, as it has also said, "the use of fuel with lower enrichments reduces proliferation risks," adoption of the industry's proposal for virtual across-the-board exemptions from the Commission's Policy can only increase proliferation risks.

The Licensees' Request for Across-the-Board Exemption from the Policy

There is currently little incentive for research reactor operators to convert to non-weapons-grade fuels, and so their opposition to the Commission's Policy in this regard is not unexpected. The primary potential incentive--protection from upgraded safeguards requirements if not in possession of HEU--has been mitigated by what was to have been a temporary deferral of the Safeguards Upgrade Rule while the RERTR program made available LEU fuels. Furthermore, the licensees' proposal to essentially overturn the HEU Policy is combined with proposals on two related matters that would drastically reduce both incentives for conversions and adequacy of protection of the facilities: the proposal to significantly weaken physical security requirements for protection against theft of HEU, and to abolish altogether long-standing requirements to protect against sabotage. While one can understand why the licensees' would like to roll back all three of the Commission's safeguards practices, it must be said that such an attempt is extremely short-sighted.

Just as the TMI accident dealt a staggering blow to the commercial nuclear power industry from which it has yet to recover, a breach of what limited security there is at research reactors could have devastating effects. The implications of theft of kilogram quantities of weapons-grade materials should give pause to those representatives of the licensees who have pursued abolition of these Commission safeguards policies because of the inconvenience they might cause the licensees. That inconvenience is miniscule compared to the potential consequences involved with a major safeguards incident.

The "LEU Study Group" Report to the Commissioners:

A report was commissioned by the NRC on an "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Fuel," under a $59,053 NRC contract.[11]

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[11] Contract no. NRC-04-83-179.

Inexplicably, the contract did not go to an independent research entity, without financial interest in the proposed regulation being assessed. Rather, arrangements were made with an organization representing the licensees--the Nuclear Engineering Department Heads Organization (NEDHO)--to set up the Study Group to conduct the research.[12]

The researchers chosen through this arrangement with NEDHO were thus all representatives of the potentially affected licensees. They included a member of NEDHO, as well as the current head of the other main licensee organization known as TRTR (Test, Research, and Training Reactors organization). The Group thus consisted of two university faculty directors and two staff managers of the reactors being assessed.[13] In one of the more awkward aspects of this arrangement, the Chairman of the Study Group was in the unique position of participating in the design of the survey, responding to it as a representative of a licensee, and assessing that response. This led to the situation of having to sign a letter addressed to himself, answering questions he had posed and thereafter assessing answers he had provided.[14]

While in no way calling into question the technical qualifications of the participants, the composition of the Study Group--composed as it was exclusively of representatives of the affected licensees and their organizations--is unfortunate. The affiliation of the authors with the licensees who are under threat of the proposed regulation will be seen by many as coloring the conlusions reached.

Chairman Palladino has been quoted as saying regarding the appropriate standards for NRC research contracts that it is "definitely unethical" for an entity under threat of regulation to do research relating to that regulation. (Inside NRC, June 29, 1981). That is sound public policy; otherwise agency funds intended for independent research could instead be going to advocates of the affected licensees to tell the agency why it should not implement an important public policy regarding them.

That the Study Group viewed the purpose of the survey as advocacy of the interests of the affected licensees is made clear in the survey letter sent out to the research reactor representatives:[15]

> "The purpose of this letter is to inform you concerning the matter /i.e., that the NRC is considering a regulation that could require, the letter said, "immediate replacement of the cores of those existing reactors capable of using LEU"/ and to request certain written material in support of university interests."

(emphasis added)

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[12] See LEU Study Group report, p. 1

[13] id.

[14] id., p. 55 and 126

[15] id, at 53

Problems With the LEU Study Group Report: Barriers to Conversion Overstated, Benefits Downplayed

It is interesting to compare the conclusions of the study performed under the auspices of the research reactor licensees' organization with those reached by Gerald Pollack in a study performed for Commissioner Gilinsky.[16/] The Pollack study concludes, "The reactor administrators are generally in favor of the conversions to LEU and would be cooperative." He goes on to conclude:

> "Now would be a good time to move rapidly on converting university reactors to LEU since: (a) the reactor people are generally in favor, (b) NRC and DOE are seriously interested, and (c) most of the technical problems are solved or seem to be near solution."

These conclusions are echoed in numerous of the responses to the LEU Study Group's survey, yet the Group's conclusions are at right angles to Pollack's--the Group essentially opposes the Commission's Policy in its entirety, arguing that if it must be enforced at all, convert only three to five research reactors (one of which has already been successfully converted) and exempt all the rest.

In advancing this suggested reversal of the Commission's August 1982 Policy (converting "to the maximum extent possible"), the Study Group advances a number of supposed barriers to converting most research reactors, barriers that, upon closer examination, appear considerably overstated. Most of the barriers are not barriers at all, but rather inconveniences--inconveniences that pale in comparison to the consequences should any of the weapons-grade material currently on site at these university reactors be stolen.

A Unique Definition of Technical Feasibility

Research reactors--despite the fact that many of them originally ran on LEU and that many others have since been converted to LEU--when the issue of conversion for proliferation reasons was first advanced by government agencies in the late 1970s were often argued to be technically incapable of operating on fuel of any lower enrichment than the weapons-grade level they are currently using. It was argued that the thermal neutron flux would dramatically drop, reducing the usefulness of the reactor as a tool for activation analysis and similar processes; some research reactor operators went so far as to assert it would be technically impossible to even go critical with an LEU core. (An example of how this misconception continues can be seen in one of the reactor operator's responses in the LEU Study Group report at p. 130, where a critical facility--requiring no excess reactivity and having no burnup--with plenty of empty spaces in the core grid is asserted to be incapable of attaining criticality without an HEU loading.)

It is now widely recognized that there are no real technical barriers to conversion of all but perhaps a couple of reactors. One simply uses fuel that compensates for the lower enrichment by increased uranium density. It

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[16/] "Converting Reactors At Academic Institutions from HEU to LEU", Sept. 22, 1983 is a simple matter essentially of removing the HEU fuel in the core and replacing with LEU fuel. If the fuel is of the same dimensions, nothing else alters; if the dimensions are different, there is a slight change in plate spacing which, particularly for all but the high power reactors, is largely inconsequential. The so-called "major" license amendment conversions described in the LEU Study Group report are merely those conversions, which if done now rather than waiting a couple of years for higher density fuels, would involve plate spacing being different than at present.

It should be recalled that the increase in density is not a major change. Plate-type fuel in particular is a dispersion type of fuel, with small amounts of uranium dispersed in a matrix of aluminum. Aside from one or two domestic university reactors, LEU fuel is either now available or will shortly be. The barriers are solely political, not technical. To enforce the Commission's Policy of reducing "to the maximum extent possible" HEU at domestic research reactors would mean conversion of all--or almost all--university reactors.

Similarly, there is no technical problem regarding flux. Flux is essentially unchanged; at best a 10% thermal flux drop, meaning that for those few applications where a 10% difference might be important one irradiates 10% longer time or at 10% greater power. For almost all research reactors, a 10% reduction in thermal neutron flux would have no effect on activities whatsoever. (It should be noted that many research reactors don't know their thermal neutron flux to anything like a 10% accuracy anyway; oftentimes flux measurements were made twenty years previous, by students, with contradictory results, and flux is generally reported to only an order of magnitude accuracy--e.g., 10^{11} n/cm^2-sec.)

There are no technical barriers.

However, the LEU Study Group report discusses what it calls such technical barriers by a rather unique definition of "technical feasibilty." The Group defines technical feasibility as anything that can be done costing less than 1% of the reactor capital cost and change in flux or operating costs of more than 5-10%.

The LEU Study Group's definition of "technical feasibility" is thus not one of technical feasibility at all but one of economic desirability. And it establishes a unique cost-benefit assumption: that costs in excess of a few thousand dollars (most of these reactors cost between $100,000 and $1,000,000 to build) outweigh the benefits of preventing a group or nation from acquiring weapons-grade nuclear materials and making a clandestine atomic bomb therefrom. This cost-benefit starting premise colors the entire rest of the analysis, because it so vastly understates the international implications of acquisition of a clandestine fission explosive and the undermining of our attempts abroad as well to reduce stockpiles of weapons-grade materials that could be stolen or diverted.

In fact, throughout the report, there is at best a few sentences mentionining the benefits of conversion in terms of reducing proliferation risks. The report assesses the Commission Policy's implications by measuring exaggerated time and financial costs against un-weighed and un-assessed risks of nuclear weapons proliferation. Measuring one without assessing the other skews the results and leads to the reactor operators' recommendation that the Commission not enforce the Policy.

Functional Impacts Overstated

The reactor operators assert conversion could take as much as 120 months per reactor to achieve. This simply is a paper tiger. A careful reading of the responses by the licensees indicated that the actual time for conversion involves down-time of the reactor of a few weeks. One shuts down, unloads HEU, and reloads LEU. Fuel loading and unloading are common occurrences at these facilities; such a function is standard whenever core maintenance is done or fuel added to increase excess reactivity, compensate for burnup, or check for fuel damage.

The start-up tests after reloading with LEU have also been overstated. A careful review of the responses indicates that these start-up tests likewise would be minimal, of a few weeks in duration. Furthermore, the benefits of such tests are ignored. One reactor operator indicates that previous start-up tests were done in part by students at the facility. That is standard--these are, after all, supposed to be training facilities. One of the reasons that use of these reactors for educational purposes has so severely declined in recent years is that the truly vital educational and research periods for them were within the first few years after start-up, when the fuel was only lightly irradiated and in-core experiments (other than simple sample irradiations) could be performed. Reviewing student theses from a number of these reactors, for example, indicates a rapid decline in such student projects after the first few years, often admitted directly in licensee documents to be because the kinds of experiments students could do were no longer possible with the irradiated fuel.

For example, one of the primary start-up tests to be performed is a measurement of the void coefficient of reactivity--what the effect is on the reactivity of the system by a certain fraction of the moderator being voided, as from boiling. This is extremely important for evaluating the safety of research reactors from the potential for a destructive power excursion of the sort that destroyed the SL-1 reactor in Idaho in the early 1960s. Many research reactors have not measured that value in twenty years. It is a good student project; it involves placing substances which simulate voids in various locations in the core and measuring changes in control rod position therefrom. To do it, however, requires relatively non-irradiated fuel because of the direct contact with the fuel involved.

The few start-up tests thus necessary--measurement of void and temperature coefficients of reactivity and flux distribution within the fuel--would take a few weeks, be good student educational projects as they were when the reactors were new, and would improve safety at the facilities by providing recent measurements of key core parameters.

Down-time involved with conversion has thus been severely overstated, as is the loss in revenue due therefrom. (Many research reactors, having had research and instructional functions decline significantly since their early days, now are used to a significant extent for sale of irradiation services commercially.) These reactors must shut down for core maintenance from time to time anyway; any experiment involving insertion of a major experiment into the core often requires core entry; and the reactors were designed for ready few removal and insertion, as that is how they are re-fueled, made ready for maintenance, and made useful for certain internal experiments. We are talking a few weeks of down time, perhaps scheduled to coincide with regular maintenance, best scheduled during academic vacation or times between quarters.

The major time asserted to be involved in the conversions involves preparation of the safety analysis report. This seems to severely overstate the reality of the situation. Many of these reactors have in the past made far more substantial modifications to their facilities than is involved with putting in LEU fuel in the place of current HEU. Many reactors have vastly increased excess reactivity loadings, changed coolant systems, upped power levels, put in pneumatic tube systems, changed irradiation facilities, and the like. The Safety Analyses performed, based on a review of scores submitted to AEC and NRC, have tended to be quite short, taking at best a few staff-weeks to prepare. In fact, a review of the licensees' letters contained in the LEU Study Group likewise indicates many think such safety analyses could be completed in a period of a very few months; this does not mean, by the way, nothing else goes on at the facility during that time, just that as part of the normal course of business (doing safety analyses on proposed engineering modifications that come up from time to time, or new experiments proposed) an analysis is performed of taking out HEU and putting in LEU. The Analysis would make an excellent project for a reactor director and a graduate student or two, perhaps even with portions provided as class projects by a nuclear engineering class.

The time necessary to wait before off-shipping the old HEU seems overstated in the Report also. It appears from a review of the supporting licensees' responses that the only technical limitation is reduction of dose rate of the old fuel, which drops rapidly. The highest power reactors report a need to hold of only 3 months--the several years indicated by one of the lower power reactors as preferable is based simply on the fact that in the past they didn't get around to off-shipping old, lightly-irradiated HEU for several years. Off-shipment could be accomplished a few months after reloading with LEU, and of course that time period represents no interference with normal activities of the facility, as the old fuel is simple in storage holes or pools.

In short, conversion is physically easy (just taking out old fuel and putting in new), the ancillary tasks (prior safety analysis and post start-up tests) are short in time scale and useful educational experience, as well as having some safety benefits.

Financial Costs Overstated

The licensees' estimate conversion costs, if all university reactors other than MIT and Missouri-Columbia were converted, would be a total of $9 million for fuel fabrication and transportations costs, and $6 million for non-fuel costs associated primarily with preparation and defense of safety analyses for the conversion. These figures are grossly inflated.

They assume, for example, $250,000 of safety analysis costs per reactor, even if a minor license amendment is required because same-size plates are used and no change is made in thermal-hydraulic characteristics (i.e., plate-spacing is the same). This is absurd. Most reactor facilities spent far less than an order of magnitude on all safety analyses ever performed at the facility--including the original one and ones for very major modifications. The entire purpose of the RERTR program is to prove the conversion technology and resolve any potential safety problems (none have really come up). Once RERTR has proved and demonstrated a particular LEU fuel, the particular safety analyses tasks and costs for the particular reactor involved will be minor. This is particularly true if the Group's proposal--a good one--involving lead reactors for each major reactor type is followed. In that case, only those very few characteristics which vary between largely identical members of the same model of reactor would have to be assessed by the licensee, with a generic analysis already having been performed that assesses the impact on reactors within that class.

Most of the $6 million estimated for non-fuel costs would not occur.

As to the $9 million estimate for fuel fabrication and transportation, that too seems quite high. At $500 per plate, a new core for most reactors would be about $132,000, half or a third that estimated in the Report. For the higher power reactors which use up several cores, the actual fuel cost of conversion could actually be less than for the lower power cores, because it is only the incremental difference between what LEU fuel would cost and what it would have cost them anyway to buy HEU.

The shipping costs seem inflated as well. Actual shipment costs for a kilo of spent HEU were less than $5000 and the primary costs are a mileage fee for the truck and drivers, irrespective of amount carried. Even assuming two armored escort vehicles and tremendous distances for travel (Joplin Missouri to Vallecitos California to a Washington State reactor to Idaho Falls back to Vallecitos to return the cask and back to Joplin) the shipping costs for all HEU at most research reactors would be $29,000, almost all of which is involved with transport of the truck from Missouri, not the transport of the fuel to the repository. These costs would thus plumet if many reactors converted and shipments were coordinated so that the truck did not drive half way across the country to and from Joplin empty.

True conversion costs seem more representative in the estimates at page 27 of the Report of $190,000 for all fuel and non-fuel expenses (although there the shipment costs still seem very high). This is considerably less than the $350,000 fuel costs and $250,000 non-fuel expenses assumed in the report per reactor, a total of $600,000 per reactor. Using the more reasonable figure, converting all but MIT and U of Mo-Columbia would cost thus less than $5 million dollars.

It could even be done far more cheaply. The University of Florida reports in the LEU Study Group report and elsewhere that it is converting from HEU plate type fuel to 4.8% SPERT oxide rods of which it has a large quantity that were donated to it from the old SPERT power excursion testing program at Idaho Falls. That fuel is thus free.

When the University of Florida says they have a "lot of " this LEU, they mean it. They have approximately 5400 pins containing 188 kgs of U-235. Under a DOE contract, they have been converting in a demonstration project. The conversion will double their flux, not reduce it, they report, and is applicable to other similar reactors. Certainly the other four Argonauts could convert similarly, with perhaps no fuel costs at all.

Lastly, the LEU Study Group report makes a big deal of potential licensing problems and the need perceived by the licensees to keep the public out of any licensing action. While understandable, such would be a serious mistake, but at any rate misperceives potential problems. It is Intervenors who are asking for conversion to LEU, and licensees who are resisting. This is a unique opportunity to avoid public hearings by taking an action that would reduce or eliminate public concerns. To fail to convert may end up costing far more.

Safety Benefits Understated Also

Conversion to LEU has numerous safety advantages as well as safeguards advantages. The Report downplays these. They are significant.

The design basis accident for most research reactors is a power excursion initiated by, for example, someone inserting a highly absorbing sample for irradiation, withdrawing control rods further to compensate for the neutron absorption, then withdrawing sample but forgetting to first reinsert control rods. It assumes that the maximum available excess reactivity is inserted into the reactor (as by withdrawing the negative-worth sample), that the reactor goes onto a power excursion in which power is increasing exponentially at a rapid rate (with e-folding times usually in the millisecond range); the reactor is considered inherently safe if the excursion is self-terminated (by negative temperature and void coefficients) before the fuel has melted or otherwise been damaged. A power excursion that was non-safe would be, for example, the tragic SL-1 accident in the early 1960s in which the fuel not only melted but a substantial portion vaporized and in which the core was disassembled by a steam explosion.

Conversion to LEU can have a very substantial favorable impact on reactor safety. The primary problem with power excursions in plate-type reactors is that there is a time lag in the activation of the self-shutdown features. Temperature must rise in the fuel meat, be transferred to the clad and from there to the coolant, coolant must vaporize and water be expelled from the core region. This takes time; in an event occurring on the millisecond time scale, the exponential rise in power may be faster than the time lag associated with the shutdown mechanism.

LEU, in contrast to HEU, has a sizeable Doppler effect due to the presence of U-238. The U-238 heats up virtually instantaneously; there is no time lag; it becomes a more effective neutron absorber; the excursion is promptly turned.

In power excursion tests at SPERT (Special Power Excursion Reactor Test) at the National Reactor Testing Station in Idaho, cores using LEU were found to be significantly more resistant to damaging power excursions than were cores using the HEU plate-type fuel found at many research reactors currently.

Furthermore, one of the LEU fuel types currently available--for conversion of both plate type and rod-type reactors--is TRIGA fuel, with part of the moderator built into the fuel itself. It too has a very prompt and strong negative temperature coefficient, far more resistant to damaging power excursions than plate-type HEU. (The SL-1, Borax-1, and Spert-ID, all destroyed in destructive power excursions were all fueled with plate HEU. It is possible to destroy a reactor with LEU or TRIGA fuel, but the reactivity insertion necessary to do it is generally far greater.)

The LEU Study Group asserts that the safey of LEU and HEU is roughly the same. This seems to understate the real safety advantages of LEU in the power excursion area. (The assertions about slightly smaller neutron lifetimes and delayed neutron fraction seem insignificant. It is to be noted, further, that at SPERT II it was found that long neutron lifetimes may not be beneficial, because just as the neutron lifetime determines how rapidly the power rises, it also determines how slowly the excursion is terminated. At SPERT II, fuel damage was found at exponential periods ten times longer than at a reactor with shorter lifetime.) The prompt temperature coefficient due to the Doppler effect in U-238 is a very important safety feature; the even more prompt feature in TRIGA LEU even more so.

Furthermore, use of an oxide LEU (as in the case of the SPERT fuel being used by the University of Florida) can substantially reduce the fire danger and risk of fuel melting. The U-AL alloy used in HEU plate fuel is flammable; an oxide fuel is far less a risk in a fire as it is already, partially at least, oxidized. Furthermore, the U-AL fuels used in HEU are in the eutectic range, very low melting (about 650°C); TRIGA and oxide fuels would have substantial protection due to a very much higher melting temperature.

Thus, conversion to LEU provides not only substantial safeguards benefits, but also safety.

The Artificial Construct of "Lifetime Core"

The licensees' proposal to essentially throw out the Commission's August 1982 Policy is based in large part on the artificial construct of reactors claimed to have "lifetime cores." This implies that the fuel in the core will never need to be removed because of very low burnup and therefore fuel reloading would never be necessary unless LEU conversion were required. This is somewhat misleading.

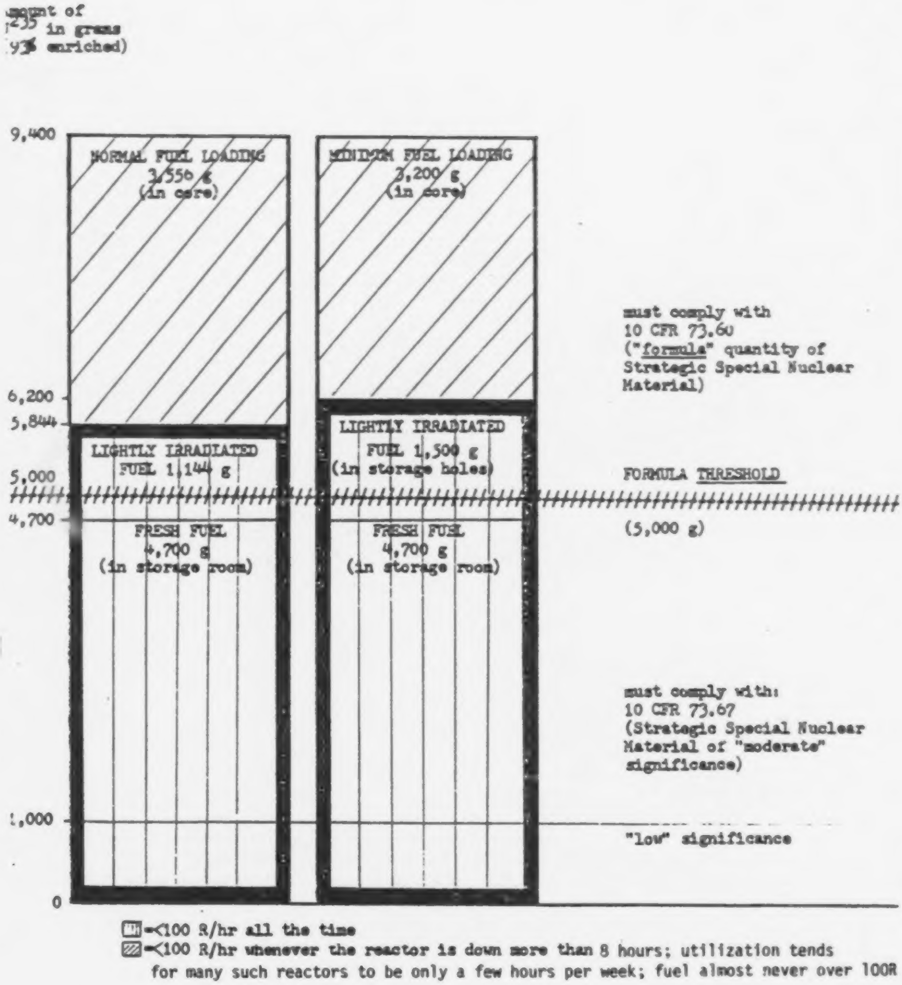
First of all, the definition of "lifetime core" used in the LEU Study Group report is actually that a reactor would not need to order new fuel in the foreseeable future because it could keep operating with the fuel in the core, in storage, or currently on order from a fabricator. This is a far-cry from what one might first think when hearing the term "lifetime" core.

The standard university reactor with HEU has a few kilos of HEU in the core, generally relatively lightly irradiated, and then other kilos of HEU in storage. The total on site is either a hair below the "formula" quantity of 5000 grams or considerably above. Thus, Washington State University would be considered a "lifetime core," for example, even though it has license authorization to possess 20 kilograms of HEU, and burns up only about .04 kilograms per year of U-235. It is "lifetime" solely by virtue of the amount of fuel in storage or on order. The same must be said of most of the so-called "lifetime cores."

One must ask, if these lifetime cores burnup so little fuel and supposedly would not need to reload in the next two decades, why have on site thousands of grams of unirradiated HEU? If the radiation of the irradiated fuel makes it somehow less of an attractive theft target, why have any of this more attractive material around if these indeed are genuinely lifetime cores?

Part of the answer to the question is that addition of fuel to these reactors is a common occurrence, happening every few years. Fuel will be damaged, thought to be leaking, or removed to increase the excess reactivity of the cores. Thus it is standard practice at even the low-burnup reactors to add fuel regularly. They are clearly not "lifetime." All that is being said is: "listen, we've got lots of this HEU on site and on order--let us use it up. If you do that, we won't have to convert." The problem is that with that lifetime arguement those reactors will, for their lifetimes, have HEU on site, attractive for theft, largely unprotected, posing a significant proliferation threat. The entire purpose of the August 1982 Policy Statement and the various initiatives on reducing HEU inventories is to prevent research reactors from having for their lifetimes inventories of weapons-grade uranium available for theft at any point in the next few decades.

SAMPLE "LIFETIME" CORE



The Licensees' Proposals

The Study Group recommends that no reactor with a "lifetime" supply of HEU on site be required to convert; that conversions of the rest (a handful) only be required when there is LEU available that would not require changing plate spacing; that priority be given to the high power reactors; and that other exemptions be provided. The long and the short of their proposal is to require conversion only of three or so reactors, if that.

The priority for high power reactors is not necessarily correct--they are the ones that may require a few years more work on advanced replacement fuels. LEU is essentially available now for the rest. And it is the lower power reactors, with their very low irradiation levels, that have the attractiveness of ease of theft and use.

The Commission has already its Policy--convert reactors "to the maximum extent possible." It is possible to convert them all; careful scrutiny would be necessary to see if MIT and U of Missouri-Columbia should be given exemptions.

Essentially all of the research reactors could be converted using currently available technology; this would involve for some the minor change of slight alteration in plate spacing. If one were to avoid any dimensional changes, about half could be converted now, the other half in a couple of years. The Commission's priorities should thus be to convert those now that can be converted now; those that should await further development of same-dimension fuel for a couple of years should begin the planning stage now and be in the second wave of conversions.

The five TRIGA reactors can all be converted to TRIGA LEU, and should be. The five Argonaut reactors can all be converted to SPERT-type LEU as at University of Florida, or to simple LEU in flat plate with technology essentially available now. Georgia Tech, and the Medium and Low Power MTR-type reactors can all be converted with technology available this year or by two years from now at the very latest (with the possible exception of Kansas State). UCSB's liquid reactor can be converted now. There is no technical barrier whatsoever; the costs are minimal; the benefits immense.

Costs

Complete conversion of university research reactors to non-weapons grade fuel could be accomplished for $5 to $7 million dollars. Even taking the licensee's figure of $15 million, believed to be considerably inflated, that remains a small fraction of the RERTR budget (expected to total $50 million upon completion.) If we are willing to spend $50 million to research conversion, we certainly should be willing to spend $5 to $15 million to carry it out.

Impossibility of Successfully Carrying Out Foreign Policy Goal of Converting Foreign Research Reactors If We Do Not Convert Domestic Reactors

Even assuming the cost if $15 million, and even were there no proliferation advantage to eliminating HEU inventories at home, that expenditure (quite small in the scheme of things) would be worth it alone on the basis of encouraging foreign conversions. Our foreign policy goal of conversions of foreign reactors will not succeed if we do not convert our own. As Dr. David Hafemeister, formerly Special Assistant to Under Secretary Benson and Deputy-Under Secretary Nye in the Department of State in the late 1970s on nuclear non-proliferation matters, has written:

> "Failure to /¯reduce HEU at home through conversion of domestic research reactors_/ would damage U.S. foreign policy interests by undercutting our government's attempts to reduce international commerce in HEU and convince other nations of the need to reduce their HEU holdings and the enrichment of their research reactor fuels. I know from personal experience in representing the State Department in such interactions with Chilean nuclear officials and representatives of Atomic Energy Commissions of other nations that it will be much more difficult for the U.S. to succeed in its policy of reduced enrichments and HEU holdings abroad if the policy is not vigorously pursued at home. The inconsistency of the US, on the one hand, denying HEU to foreign research reactors while, at the same time, oversupplying research reactors at home with HEU that is not properly safeguarded would not be lost on the nations we are trying to influence."

$5, $10, or $15 million spent to convert domestic university reactors--if for no other reason than to remove a major stumbling block to conversion of foreign reactors--would be money very well spent. The same amount spent to prevent diversion or theft of HEU from U.S. reactors would also be well spent. Put together, it's a real "steal."

The Alternative to Conversion: Effective Protection Against Theft

The Commission has essentially two choices on the matter of HEU at university reactors: convert them to LEU, or force them to protect the material consistent with the consequences of its theft or diversion. If the university community is worried about the impacts of the former, which would be minimal, they should be very worried about the impacts of the only other choice that failure to convert would leave open to the Commission: significantly upgraded security.

When the Commission approved the Safeguards Upgrade Rule in the late 1970s, nonpower reactors were temporarily exempted from its effect. That deferral was to be short-lived, based on the soon-to-be available LEU conversion fuels being developed by RERTR. Those fuels are now essentially available, and either research reactors should be converted, or protection upgraded.

The licensees have proposed that they have their cake and eat it too: that they be exempted from LEU conversion and that physical security requirements for HEU be largely relaxed. Both proposals go in the wrong direction.

The Need for HEU Conversion in Perspective: HEU As It Is on These College Campuses

The fuel at most of the reactors with HEU cannot be kept anywhere near the 100 Rem/hour level.It is protected almost exclusively by relatively primitive and easily compromised burglar alarm systems, alarming at campus police stations, with relatively untrained "unicops" to respond as they would to any alarm on campus. There are few if any physical barriers to entry of any effectiveness, and the fuel is readily removeable. The Los Alamos study performed for the Commission on this issue estimates removal of the HEU at the standard research reactor could be accomplished in 1.25 hours, with times as low as .5 hours possible.

Universities pride themselves, rightly so, on their open atmosphere. The kind of security necessary to protect atomic bomb material is inconsistent with that atmosphere. That explains a large part of the reason why research reactor licensees have lobbied the Commission so hard to relax or defer or eliminate entirely physical security requirements for protecting against theft or diversion of the highly enriched uranium they have on campus.

That simple understanding--that protection sufficient to protect bomb-grade material from theft is inconsistent with the environment in which that material is found at these research reactors--speaks volumes about the need to convert these facilities from HEU to LEU. Security cannot be--and is not--anywhere near sufficient to protect material of this incredible sensitivity. Either the universities should agree to truly safeguard this material--which they refuse to do--or they should not have it on site. They can do all they wish to do with LEU and not have the security problem presence of weapons-grade material produces. An examination of the situation at many of these research reactors is helpful in putting in context the HEU policy issues.

Bomb-Grade Material in Filing Cabinets, Walls of Glass, Inoperable Alarms

The following examples of security problems at research reactors possessing HEU are taken from a survey of approximately 1/3 of those in the nation. The material all comes from information in the public record. However, although we were able to obtain the material from public sources, we do not feel it appropriate to identify with specificity where each particular problem is associated with which particular reactor. Potential thieves of HEU can get too much information on that score already. It should be understood, however, that this material comes from inspection reports and other publicly available material about a number of university-based reactors and should not be assumed to pertain to any specific one.

** One research reactor, built twenty years ago when the campus wished to make the reactor a campus "showplace," was built with essentially all walls and doors made out of glass so that people passing by could see directly into the reactor room. Inspectors years later expressed concern about this from a security point of view--glass walls do not provide much barrier to penetration!

** At another facility, one key was lost and another duplicated without authorization, yet the inspectors found that one year later there had still been no corrective action (i.e., no rekeying).

** At another facility, the security plan requires the alarm system to register a security violation (i.e., the alarms must work). The inspector cited the licensee for violation of this requirement when he had the alarm system armed and walked around the reactor room for a considerable period of time without being able to set off the alarm!

** Similarly, an inspector found a reactor security system to have been plagued with false alarms, so the licensee had "tuned down" the alarm sensitivity to a level that made it impossible to detect intrusion. Further, it was found that the alarm system installed by the licensee was a kind that the AEC had found defective and forbidden for use in AEC facilities.

** Another such alarm system was found to be tied into the computer at the campus police station. It was found that this was a problem because of the relative ease in disabling the computer, or modifying its program (a forerunner perhaps of the recent reports of teenagers entering and altering other people's and institution's computer systems.)

** It was found at one facility that at certain times there was only one campus police officer available to respond to an alarm at the reactor, and that furthermore there were no procedures as to what to do once there nor who to call on for support if needed.

** One report cites the requirement that "key locks should provide a high degree of resistance to opening by force or tamper techniques.... [However] In several of the locks it was noted ...failed to operate." "The inspector demonstrated to licensee staff that the door ... could be opened using a small screwdriver."

** In another facility, the doors to the reactor facility were all built with the hinges on the outside, making possible easy entry into the facility without even having to tamper with the locks. Simply by removing the hinges one could gain entry by essentially removing the door itself.

** Another inspection report revealed nuclear material "unaccounted for" (MUF), inventory record poor, poor burn-up records, no inventory procedures, "internal controls were minimal"

** Another report found a violation at a particular facility because keys had been given out to people without their taking the required training.

** In other situations, keys had been given out to people who had later left the university without the keys being retrieved or the facility rekeyed.

** At another institution, an inspector cited the licensee for having left the key to the reactor in the control console without anyone present; the key could thus have been taken by anyone nearby.

** In other facilities, the key to the reactor must be given to maintenance people whenever they are to do maintenance in a non-reactor related room restricted entry because of "gamma and neutron shine". Thus, a vital key is given out for long periods because the facility didn't spend the money for a true interlock system that would have prevented personnel above the reactor room while the reactor was on.

** Another facility was found to have "no material control and accounting proceedures"

** Drawings in the security plan were incomplete--ten feet were missing from the center of the building drawings.

** The facility built of glass had other problems: "The south side of this building is particularly vulnerable in that trees and shrubs prevent an isolation zone. In addition, bricks are stacked near door '5' that would completely mask a potential intruder."

** It was observed at one facility that people were given entry to the building by a student inside opening the door when people knocked. Methods of preventing unauthorized persons from knocking and forcing entry when door was opened weren't in place.

** "Effective key controls have not been established. For example, a master key issued to an individual no longer on the faculty has not been retrieved and three master keys are known to have been lost. However, the locks associated with those keys have not been rekeyed.

** "There were no specific procedures for response to alarms by campus police and no provisions for compensatory measures in case of alarm system failure."

** The alarm system at one facility didn't differentiate between alarms at the reactor and elsewhere in the building.

** "There is no commitment in the security plan to periodic key inventories and other provisions of Regulatory Guide 5.12."

** "The reactor control room is not locked during times of occupancy."

** "Discussions with operations personnel and examination of records of the Campus Police Department revealed that on September 13, 1977, the east door to the Nuclear Reactor Building was found unlocked by campus police at 0207 hours. The Nuclear Reactor Building was inspected by the police and then secured."

** A facility was found to have defective door locking mechanisms and committed to correcting the problem. A year later the next inspection found the commitment had not been lived up to and the problems remained.

** Despite telling NRR that the control room was to be protected, "The inspector determined that this has not yet been implemented."

** An access key was misplaced in March and the situation not reviewed by the security committee until half a year later; did not rekey.

"Vaults" that are just normal rooms, "Safes" that are Filing Cabinets

Some facilities describe their storage facilities for unirradiated HEU as "vaults" and their storage vessels as "safes."

For at least some of these facilities, the vaults are normal rooms with normal doors--one in fact is just chain link fence for a door.

And for more than one facility, the so-called "safe" was merely a filing cabinet with a combination lock!

Irradiated Fuel at Very Low Irradiation Levels

It might be believed that for reactors where most of the fuel is in the core, and only a few kilos in storage, that the irradiation of the in-core fuel provides some protection. This is not true for most of the research reactors.

The NRC Staff has already reported to the Commissioners that it is impossible for most research reactors to keep fuel even at the 100 Rem/hour level. A reference calculation is attached to demonstrate how quickly most reactors' fuel drops below that level and how low the irradiation levels really are. It drops below 100 Rem/hour in just 8 hours of shutdown; down to a level of 11 Rem/hour in a week. Many of these facilities only operate a few hours per week; weeks can go by without operation.

Given the Los Alamos estimate of 1.25 hours to complete the theft, doses in the legal range for nuclear workers are all that could be expected for the thieves--particularly if, as is likely, several participate in the theft.

FUEL BUNDLE RADIATION DOSE RATE AFTER SHUTDOWN-- REFERENCE 100 KW RESEARCH REACTOR OPERATED MINIMUM OF TWO FULL POWER HOURS PER WEEK*

TIME AFTER SHUTDOWN	DOSE RATE PER BUNDLE-REMS/HR
3 HRS	92
1 DAY	33.5
7 DAYS	11
14 DAYS	8.5
21 DAYS	7.3
4 WEEKS	6.5

CALCULATIONS BY DR. ROGER KOHN.

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* NORMAL OPERATING LEVEL FOR MANY SUB-MW UNIVERSITY REACTORS

Theft of the Weapons-Grade Uranium on these Campuses Relatively Easy

The equipment for the theft is all at the facilities themselves. The fuel handling tools, the cranes for removal of the core plug (if not a pool reactor), and the electronic equipment useful in bypassing the burglar alarm systems (by looping the signal wire and mimicking any line supervision that might exist). Once done, one could work all night and no one would know it.

These research reactors are made for easy core entry and fuel handling. Students are to do it; core entry must be made often for maintenance; even so simple and common a matter as flux mapping requires removal of shield blocks in those few cores without open pools so that foils can be placed in foil slots. They are designed for entry and fuel removal; unauthorized fuel removal can be readily and easily accomplished. The only barrier in most cases is a burglar alarm system which is child's play to compromise, given the economic value of the material to be stolen, the likely investment a potential thief would put into achieving such material, and the knowledge of people interested to begin with in such nuclear materials.

The unirradiated material would be far easier even to steal; generally in an even simpler location for removal.

The important thing to realize is that weapons-grade uranium is being stored in normal labs at normal universities, with scores of students having access to the facilities and the protection essentially the same as that of the student store or other similar alarmed facility on campus. These facilities where weapons-grade uranium are stored are protected the way any other place on campus is, with perhaps somewhat more sophisticated intrusion alarm systems, but nowhere near the sophistication necessary to prevent their being compromised by someone interested in stealing material for a bomb. Recall also that on site of many of these facilities is half a million or a million dollars worth of bomb-grade uranium, several plutonium sources that could be used in constructing a weapon or as a radiological dispersal weapon, and in some cases, half a million dollars of heavy water in barrels. A thief could make quite a lot financially from such a theft; a thief interested in making a weapon would have even more incentive. Primitive matters such as bypassing alarm wires would be a piece of cake to such a thief.

These reactors would have three places where fuel is stored: lightly irradiated fuel in core, readily retrievable; lightly irradiated fuel in storage, often in holes in the floor near the reactor with plugs easily removed or in storage pools; and fresh fuel, either in a back storage room used for other storage or in a storage pool. One could get in and out without detection without problem, leaving with many kilos of weapons material; even if detected, the campus police officers are unlikely to be able to deal effectively with determined adversaries prepared to steal weapons material to make a clandestine fission explosive.

Stealing 4900 grams of the HEU as bad as 5100 grams: "Formula Quantity" Wrong

As Dr. Taylor has indicated, theft of kilogram quantities of HEU would be of grave concern. Given the large reduction in HEU quantities needed for an implosion device compared to the standard references to minimum quantities at normal density, unprotected and underprotected HEU at university reactors in the kilogram range pose major safeguards and proliferation hazards.

Far more than a detection and reporting ability is needed, but some university reactor personnel believe all they must be able to do is let someone know the HEU has been stolen sometime after the fact. This is a terribly dagerous attitude and invites theft of extraordinarily dangerous material.

CONCLUSION

The Commission's Policy on converting research reactors to LEU to the maximum extent possible is highly responsible, internationally acclaimed, and the right thing to do.

There are no technical barriers to such conversion. "The maximum extent possible" is convert all of them--with the possible exception of MIT and U of Mo-Columbia, after careful scrutiny.

The proposed exemption for "lifetime cores" is an artifice that would permit lifetime possession of HEU, in reactors where the radioactivity level is far below anything that could be considered "self-protecting." It would gut the Commission's Policy and throw a monkey-wrench into attempts to convert foreign reactors, because they would see we were only converting 3-5 of our own reactors, exempting the rest.

Most research reactors cannot get anywhere near 100 rem/hour "self-protection" levels for fuel bundles.

The 5000 grams "formula quantity" is not founded in fact; reactors with less than that quantity are leaving their kilogram amounts of HEU almost entirely unprotected.

HEU at college campuses is generally protected almost entirely by a burglar alarm system tied into a college campus. These facilities are protected the way other facilities are on campus, and a determined thief interested in weapons-grade uranium would have little problem successfully stealing the material, probably without detection.

Security is very lax at these facilities; the danger of HEU theft is not taken seriously; extraordinary security violations are routine, with correction slow or non-existent; relaxation any further of security requirements goes in the wrong direction. Security for weapons-grade materials should be upgraded, both as incentive for conversion and because if HEU is to be possessed, security must be adequate to prevent its theft by a determined group intent on acquiring a nuclear weapon.

The Commission should enforce its August 1982 Policy. University and other research reactors in this country should be converted to low enriched fuels, rapidly and diligently. Excuses from the licensees should not prevent proceeding on an important public policy course. Theft of HEU would have consequences of a most grave sort to the international community.

Conversion of research reactors to LEU is a sweet, technical fix that meets everyone's needs. The research reactor community can do all that it wishes to do with its reactors; the non-proliferation community can breathe easier that weapons-grade uranium here or abroad will not fall into the hands of groups or nations intent on acquiring atomic weapons.

This is one of the few U.S. nonproliferation initiatives (reduced enrichement) with wide international and domestic support. To "enforce" the Commission's Policy by exempting virtually all research reactors in this country from it, as proposed by the research reactor licensees, would be a very grave mistake and could result in a serious setback to nonproliferation efforts.

The consequences would be very serious were any of the HEU at these reactors stolen or diverted. The solution is simple: let the reactors keep operating, but with fuel that if stolen is no proliferation threat. A sweet, technical, inexpensive solution to an important aspect of one óf the most important issues of our time.

Note: The views expressed in this paper are those of the author and not necessarily those of the University of California.

STATEMENT OF ROGER L. KOHN, PH.D., J.D.
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
AND THE
SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
OF THE
U.S. HOUSE OF REPRESENTATIVES
CONCERNING THE CONVERSION OF RESEARCH REACTORS FROM HIGHLY ENRICHED TO LOW ENRICHED URANIUM FUEL
OCTOBER 12, 1984

My name is Roger L. Kohn. I am an attorney with experience in nuclear-energy regulation law and litigation. I have also been, for over twenty years, a physicist and systems analyst, with a Ph.D. in applied physics.

I understand that the Nuclear Regulatory Commission is considering a proposed regulation to require conversion of research reactors to low-enriched fuel. I support such conversion, and urge that it be mandatory, immediate, and with only the narrowest of exceptions.

I believe that mandatory conversion is necessary because of the risk of theft of high-enriched weapons-grade uranium (HEU) from research reactors and because there are no sufficient countervailing benefits to offset the risk.

Contributing to the risk are at least three policies: (1) Research reactors, located as they often are in the university environment, cannot, consistent with the open-access policies of educational facilities, be protected adequately as can other reactors; (2) It is my understanding that the NRC Staff's view of its practice is that only post-reporting of theft, but not prevention of theft, is required; and (3) Reliance on self-protection of fuel from theft by its radiation level is misplaced.

In addition to the unfortunate practice of not requiring protection against theft, I am concerned about the reliance on the radiation level of the fuel as a deterrent to theft. Research reactors are generally of such low operating power, and thus contain such lightly irradiated fuel, that the maximum radiation doses to individual members of a group of thieves would not be substantially larger than the doses permitted nuclear workers in exceptional circumstances. Such doses would certainly be far from disabling. In more typical cases, the dose from individual, separable fuel bundles such as I have calculated for a university research reactor is far less, and the fresh fuel in storage at such a reactor poses no radiation threat to a thief. Thus there is no effective deterrent effect from fuel radiation levels at these reactors.

If universities cannot, consistent with budgetary constraints and open-access policies, protect against theft of the weapons-grade uranium that they possess, and since the country and the world cannot tolerate the diversion of such fuel, then the clear, reasonable, and practicable solution is mandatory, immediate, and enforced conversion to low-enriched uranium.

In summary, the use of HEU fuel creates risk of diversion and misuse of the weapons-grade fuel. Additional security measures are presently necessary to protect HEU from diversion. Far more straightforward and risk-free than additional costly yet failure-prone security measures would be the use of low-enriched uranium fuel, and the substitution now of LEU for HEU where it it now in use.

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Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

NUCLEAR CONTROL INSTITUTE

1000 Connecticut Avenue, N.W., Suite 406, Washington, D.C 20036 (202) 822-8444

October 12, 1984

The Honorable Don Fuqua
Chairman, Subcommittee on Energy Development
and Applications
The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy Research and
Production
Committee on Science and Technology
House of Representatives
Suite 2321
Rayburn House Office Building
Washington, D.C. 20515

Dear Chairmen Fuqua and Lloyd:

Thank you for your letter of September 27. I am disappointed that you have no plans to conduct further hearings on the proposed NRC rule requiring conversion of licensed research and test reactors from highly enriched to low enriched uranium fuels. Because of the urgency of this matter in the context of general nonproliferation efforts and of preventing access by terrorists to weapons-grade nuclear material, your Subcommittees should hear testimony from non-governmental witnesses who support, as well as those who oppose, the rule. I ask you to reconsider your decision. At the same time, I appreciate this opportunity to submit the views of Nuclear Control Institute for inclusion in the record of the September 25 hearing.

I am submitting for the hearing record, in addition to this letter, my testimony and that of Dr. Theodore B. Taylor before the Nuclear Regulatory Commission, which address many of the issues raised by opponents of the rule at your hearing. I am also submitting for the record the Institute's "Issue Brief" on this matter. These items are attached.

One claim of the opponents of the rule is that the conversion to LEU would reduce the research capabilities of the reactors. In his testimony, Dr. Taylor makes clear that the universities already have restricted themselves by limiting the power of their reactors. If they want to compensate for the loss in neutron flux caused by the conversion, he points out, they can increase the power level of the reactors. Moreover, as Daniel Hirsch of the Committee to Bridge the Gap noted in his testimony before the NRC, most reactors cannot even detect the changes in neutron flux in the range that the conversion would create.

Another criticism of the rule takes the form of questioning its effectiveness in attaining the U.S. foreign policy objective of reducing the amount of HEU in circulation throughout the world. My testimony points out that, in fact, the Reduced Enrichment for Test Reactor (RERTR) program is both practicable and widely supported by the international community, including those nations whose imports of HEU from the United States would be phased out. Carlton Stoiber of the State Department corroborates this view in his testimony when he praises "the spirit of willing cooperation that has prevailed throughout the course of the [RERTR] program" and the "unanimous agreement among foreign governments and programs that reduced trade flows in HEU could help reduce the risks of nuclear proliferation."

This spirit of cooperation would be damaged severely if the United States failed to impose the same restrictions on itself that it seeks others to impose upon themselves. This very issue came up at the RERTR annual meeting in Japan last November. It is puzzling, therefore, that Mr. Stoiber states, as did Ambassador Richard Kennedy in an earlier letter to the NRC, that the proposed rule would have only "some marginal effect" on U.S. efforts to attain conversion of research reactors in other countries.

A third objection to the rule addresses the possibility of theft of the highly enriched uranium. Opponents of the rule downplay both the possibility of such a theft and its impact if one were actually to occur. Dr. Taylor's testimony makes it abundantly clear that the relatively small but highly significant quantities of HEU presently at individual research reactors would be a cause for grave concern if they fell into the hands of terrorists, either as material for a weapon or as an instrument of blackmail. And Mr. Hirsch has documented in his testimony the inexcusably lax security measures that exist at many university reactors, resulting in doors left unlocked and fresh fuel stored in filing cabinets. Moreover, the fuel often is not self-protecting. When the reactors are run infrequently, as is often the case, radiation levels fall below the point that would assure that the fuel is self-protecting.

Critics of the rule also have claimed that there is no evidence to indicate that terrorists will target nuclear facilities. However, as NRC Commissioner Frederick M. Bernthal testified at your hearing, "acts by international terrorists have repeatedly shown that a threat can materialize without sufficient warning from intelligence sources." Indeed, few experts would have predicted five years ago that U.S. embassies and military installations would become terrorist targets.

Finally, the overriding concern of most critics of the rule is an economic one, with many predicting that added costs in connection with conversion will force their facilities to shut down. This argument is specious because the Commission has made clear that implementation of the rule will be contingent upon the availability of federal funds to cover conversion costs. And Congress already has appropriated $2 million toward this effort. This amount is more than enough to begin conversion, even if one accepts the operators' grossly inflated cost estimate of $15 million. Even if this were the true cost (the likely cost is in the $5 to $10 million range), it is a small price to pay for removing atom-bomb material from the nation's campuses.

Another element of the operators' cost concerns is their fear that they will have to undergo a relicensing procedure that would allow opposition groups to intervene, thus drawing them into lengthy, frustrating, and costly litigation. This fear is entirely unfounded. A changeover of the type required under the NRC rule would involve not a relicensing but rather a minor amendment of the current license. Outside groups would be able to intervene only on the question of that amendment. In the entire history of the U.S. nuclear program, there never has been an intervention on an amendment to a research reactor operating license. Moreover, it would be antithetical to the interests of the groups involved to engage in legal action that would delay conversion. Spokesmen for the Committee to Bridge the Gap, a major supporter of the conversion effort, have said that they and similar groups would work to prevent any obstruction of the conversion procedure, but would strongly consider interventions to upgrade security at the reactors, at the operators' expense, if the operators refused to allow conversion or if the NRC backed away from the proposed rule requiring such conversion.

The NRC rule deserves to be implemented. At the very least it is entitled to receiving a balanced hearing before your subcommittees. I urge you to schedule another hearing before reaching any final conclusions on this matter.

Sincerely,

Paul L. Leventhal
President

Attachments

Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

NUCLEAR CONTROL INSTITUTE

1000 Connecticut Avenue, N.W., Suite 406, Washington, D.C. 20036 (202) 822-8444

STATEMENT OF PAUL L. LEVENTHAL

Before The Nuclear Regulatory Commission
Regarding the Need to Convert Domestic Research Reactors
From Highly Enriched to Low-Enriched Uranium Fuels
January 27, 1984

I appreciate the decision of the Commission to have the additional series of meetings being held today to consider the non-proliferation policy and security implications of a domestic rule on converting research reactors from highly enriched to low-enriched uranium fuels. Thank you for the opportunity to appear at this public session.

I am Paul Leventhal, President of Nuclear Control Institute, a non-profit, educational organization concerned with the dangers of nuclear-weapons proliferation. In 1972-1976, I was Special Counsel to the Senate Government Operations Committee where I had responsibility for investigations, hearings and drafting legislation leading to enactment of the Energy Reorganization Act of 1974 and the Nuclear Non-Proliferation Act of 1978. In 1978-1980, I was Staff Director of the Senate Nuclear Regulation Subcommittee, in which capacity I was also Co-Director of the Special Senate Investigation of the Three Mile Island Nuclear Accident. I am accompanied by John Buell, Issues Director of Nuclear Control Institute, who assisted in the preparation of this statement.

Also with me today is David Albright, Research Associate of the Federation of American Scientists, who has prepared data referred to in this statement and who is submitting to the Commission a letter from him and Dr. Frank von Hippel, Chairman of FAS, and an additional report on the reduced enrichment program.

There are many technically complex and politically difficult issues to contend with in seeking to prevent the proliferation of nuclear weapons, but the use of highly enriched, weapons-grade uranium as fuel for civilian research reactors stands out as one problem that can be solved with relative ease.

In contrast to the seemingly insurmountable technological barriers to achieving effective controls on some sensitive nuclear materials and technologies, the Reduced Enrichment for Research and Test Reactors (RERTR) Program provides a readily achievable solution. Although many U.S. non-proliferation initiatives meet with stiff political resistance abroad, the U.S. objective of phasing out exports of HEU in conjunction with cooperative efforts to convert research reactors to LEU has been received surprisingly well by foreign governments.

There is however, a major potential obstacle to achieving this important non-proliferation objective. If the United States fails to practice at home what we preach abroad, the implicit message will not be lost on the nations we are trying to influence to eliminate highly enriched uranium from their research reactor programs.

The Commission is to be commended for the leadership role it played on August 24, 1982 by issuing a policy statement (47 FR 3006-3007) announcing its interest "in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors." The statement closed with the following significant observation and commitment:

> The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. research reactor operators.

Given the Commission's forthright acknowledgement of the linkage between domestic and foreign conversion of research reactors to lower enriched fuel, the Commission's development of a proposed domestic rule on this question is certain to have profound international implications. We would urge, therefore, that all domestic research reactors under the Commission's authority be required to convert to low-enriched uranium as soon as such fuel is available.

Such an unambiguous rule would have the effect not only of encouraging the conversion of foreign reactors that now require reloads of HEU, but would set an example for the conversion of smaller reactors that have a lifetime supply of fuel on site. Dr. Taylor has made clear that the existence of even kilogram quantities of HEU, whether irradiated or not, presents an unacceptable risk of theft in civilian research programs.

A strong domestic rule by the Commission can also serve to bolster the sometimes lagging support for the RERTR Program within the Administration and to encourage the Department of Energy to begin conversion of its research reactors to LEU.

The security and non-proliferation stakes are quite high.

There are currently 137 research and test reactors in 34 countries which use HEU as fuel. More than a third of these reactors (45) are in the United States. According to data assembled by the RERTR Program, the annual requirement of U-235 for these reactors is 1,046 kilograms of which the U.S. provides 1,030 kilograms, or 99 percent. There are 4,100 kilograms of U-235 in circulation at any one time — enough for at least 205 atomic bombs on the basis of a conservative estimate of 20 kilograms per weapon.

According to data assembled by David Albright of FAS, the United States has exported some 23,590 kilograms of highly enriched uranium (containing 16,980 kilograms of U-235) to 43 nations from the start of the Atoms for Peace program through 1982. The bar graph showing annual exports indicates there were a number of years when exports of HEU exceeded the annual foreign requirement of about 500 kilograms of U-235. Apparently, in those years, the United States was supplying lifetime cores to the 37 low-powered research reactors that have little or no reload requirements.

Since the mid-1970s there is a growing consensus that the use of HEU in civilian research programs presents an unwarranted proliferation risk and should be discontinued in view of the feasibility of converting to lower enriched fuel. The summary report of the International Fuel Cycle Evaluation (INFCE, 1980) stated that it is feasible to markedly reduce the enrichment of a great majority of research reactors and endorsed the conversion of HEU-fueled research reactors to lower enrichment.

In 1977, the United States announced a nuclear non-proliferation initiative to significantly reduce U.S.-supplied inventories of HEU for fueling research reactors and announced plans for the RERTR Program to develop a low enriched (20% U-235 or less) alternative fuels. The RERTR Program generally has functioned well since 1978 and already has developed LEU fuels suitable for most of the research reactors in the world.

This success has come despite less than enthusiastic support from certain quarters within the Department of Energy, the lead agency for the program. The GAO has reported that in 1981, DOE requested only $1 million for the program — one fifth of the previous years funding. Eventually another $1.6 million was raised from other programs in DOE, State and ACDA, but that still left funding at half of what it had been the previous year. Since that time, funding has been gradually increased, but it has taken three years to reach levels set by the previous Administration. Even now there are signs of a continuing struggle by proponents of the program to gain adequate funding.

The potential of a strong, comprehensive rule by the Commission influencing the direction of Energy Department's own research reactor program should not be overlooked. Currently, NRC-licensed research reactors account for only ten percent of the annual civilian domestic HEU requirement. The other 90 percent is used by the 15 non-defense reactors operated by DOE. According to data developed by the RERTR Program, all but one of these reactors could convert to the LEU fuel now being developed. Even the remaining reactor, the ATR in Idaho, can be converted if it is decided that the reduction in performance characteristics is an acceptable price to pay for eliminating the use of HEU from the research reactor program.

Although foreign support of the RERTR Program has been encouraging, there remains the outstanding issue of whether the United States will take the lead by moving promptly toward LEU conversion. As recently as last November at the RERTR annual meeting in Japan, the issue of "even handedness" by the United States was raised at a roundtable discussion. Commissioner Gilinsky assured the participants that the Commission "intends to demonstrate that conversion to low enriched fuel is not a difficult process by taking steps to enable domestic reactors operating in the United States to convert to low enriched fuels," and he cited the proposed rulemaking that is the subject of today's meeting.

The Commission should set an example by promulgating a rule that requires conversion not only of the university reactors under its jurisdiction, but the NRC-licensed government and industry reactors as well: the National Bureau of Standards Reactor, the Union Carbide Reactor, the General Atomic Triga-F Reactor, the Westinghouse Nuclear Training Reactor, the General Electric Test Reactor, and the General Electric Nuclear Training Reactor.

The conversion of university reactors to LEU fuel provides the additional benefit of eliminating the need for severe security measures that are not appropriate to institutions of learning. As noted by Dr. Taylor, such security measures are needed at any facility using even kilogram quantities of this material. In fact, such security measures are generally not instituted (as is outlined in Mr. Hirsch's testimony) due to their being antithetical to a university environment. Conversion to LEU is the easiest solution to this problem.

Finally, if highly enriched uranium were no longer required to fuel civilian research reactors, and if no further production of HEU is required for the weapons stockpile or for naval propulsion fuel, as may well be the case, the basis would be established for suspending further production of HEU and even for blending down existing HEU stocks into low enriched uranium for use in civilian research and power programs.

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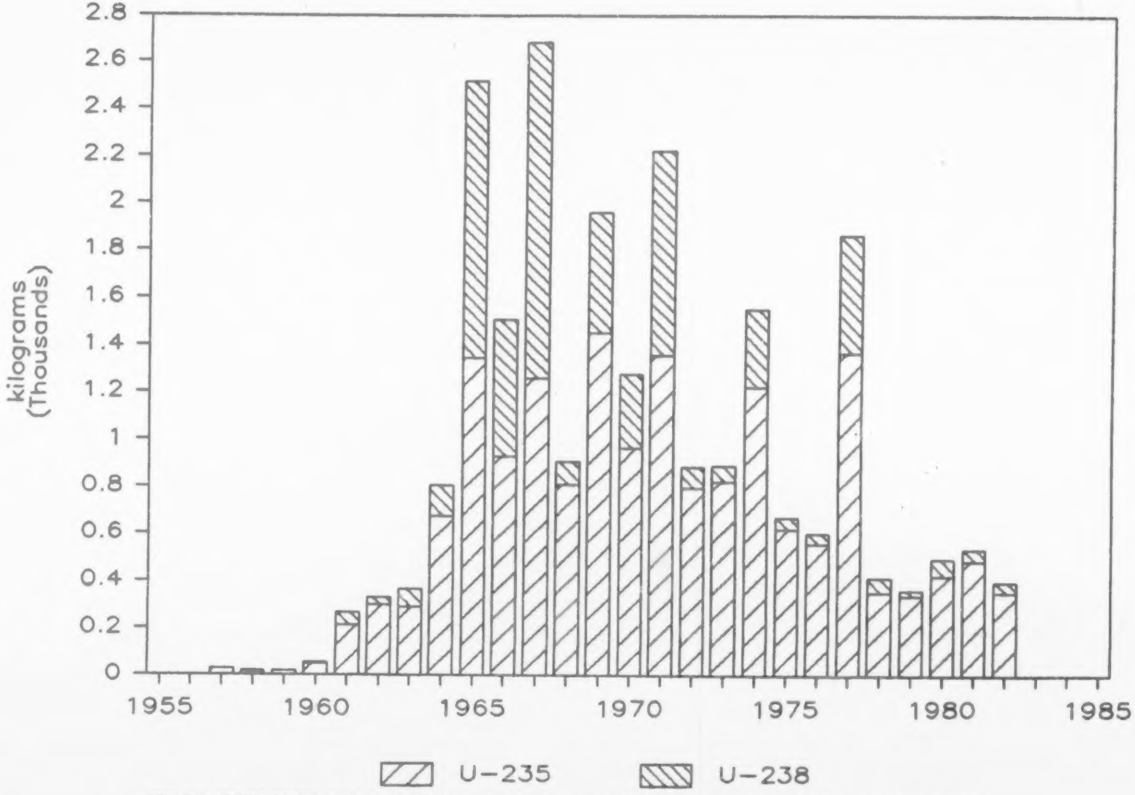
ANNUAL U.S. EXPORTS OF HEU



GRAPH PREPARED BY DAVID ALBRIGHT, FEDERATION OF AMERICAN SCIENTISTS

SOURCE: DEPT. OF ENERGY

Exports[a] of HEU From 1954 Through 1982

Country	HEU (kg)[b]	Contained U-235 (kg)[b]	% U-235 (average)
Argentina	94	59	63
Austria	9.8	7.3	75
Australia	10	9.2	90
Belgium	187	159	85
Bolivia	c	c	-
Brazil	7.7	7.2	93
Canada	1,861	1,724	93
Columbia	3.1	2.8	90
Czech.	c	c	-
Denmark	26	24	92
Finland	3.9	.77	20
France	6,268	4,655	74
W. Germany	9,990	6,611	66
Greece	6.6	6.1	93
IAEA	.31	.25	81
Ireland	c	c	-
Indonesia	.018	.13	72
India	.098	.081	83
Israel	19	17	90
Iran	5.5	5.2	93
Italy	382	307	80
Japan	1,995	946	47
Korea	30	18	62
Malaysia	c	c	-
Mexico	30	12	42
Netherlands	63	57	89
Norway	.01	.008	80
Pakistan	5.8	5.2	90
Philippines	3.3	3.1	93
Portugal	7.7	7.2	93
Romania	39	37	93
South Africa	33	30	92
Spain	9.4	8.3	88
Sweden	148	133	90
Switzerland	8.8	8.0	91
Taiwan	9.9	9.2	93
Thailand	5.3	4.8	90
Turkey	5.3	4.8	90
U. Kingdom	2,301	2,141	93

(Table continued on back)

Country	HEU (kg)[b]	Contained U-235 (kg)[b]	% U-235 (average)
Uruguay	c	c	-
Venezuela	.011	.009	82
Vietnam	.39	.08	21
Yugoslavia	17	5.9	35
Zaire	1.4	.28	20
Total	23,590	16,980	72

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a. Figures represent shipments by U.S. to foreign countries. Returns to U.S. and retransfers to other foreign countries are not reflected in the data.
b. Amounts rounded off
c. A few grams at most.

Source: Department of Energy, Nuclear Materials Management and Safeguards System

Table prepared by David Albright, Federation of American Scientists

Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

NUCLEAR CONTROL INSTITUTE

1000 Connecticut Avenue, N.W., Suite 406, Washington, D.C. 20036 (202) 822-8444

STATEMENT OF DR. THEODORE B. TAYLOR

Before the Nuclear Regulatory Commission
Regarding the Need to Convert Domestic Research Reactors
From Highly Enriched to Low-Enriched Uranium Fuels
January 27, 1984

From 1949 to 1956 I worked on the design of nuclear explosives at the Los Alamos Scientific Laboratory. From 1956 to 1964 I worked at the General Atomic Division of General Dynamics Corporation, during which period I helped design the TRIGA research reactor. From 1964 to 1966 I was Deputy Director (Scientific) of the Defense Atomic Support Agency in Washington. The following years have been spent as an independent consultant to the U.S. Atomic Energy Commission and a number of other organizations, working on nuclear safeguards issues and other energy-related matters. I served on the Presidential Commission on the Accident at Three Mile Island. I am co-author of *Nuclear Theft: Risks and Safeguards*, as well as a number of other books and articles dealing with nuclear safeguards and related subjects. This morning I appear as a member of the Board of Directors of Nuclear Control Institute. A more detailed statement of my professional qualifications is attached.

It is my opinion that all domestic research reactors under the licensing authority of the Nuclear Regulatory Commission should be required to convert from highly enriched uranium (HEU) to low-enriched uranium (LEU) fuels as soon as the LEU fuels are available. I know of no reason that could justify the unique safeguards risks associated with continued operation of these reactors with materials so internationally dangerous. I come to this conclusion as a former designer of both nuclear weapons and research reactors, and from extensive involvement in the field of nuclear safeguards. The basis for this conclusion[1] is as follows:

Weapons Implications

Uranium enriched to 93% in the isotope ^{235}U is weapons-grade. It is weapons-grade because it is directly usable in nuclear weapons without any further isotopic enrichment. Because it is weapons-grade material, 93% enriched uranium is a potentially attractive target for theft or diversion by terrorist groups or nations intent on acquiring nuclear weapons. The potential consequences of such theft or diversion are very grave.

A group or nation capable of making nuclear weapons from 93% enriched uranium would not have any significant difficulty in separating the uranium from the uranium-aluminum eutectic in which it is found in flat-plate MTR-type research reactor fuel. The methods for doing that are widely published and fairly straightforward.[2]

Such a national or subnational group also would not have substantial difficulty in removing the uranium from MTR-type research reactor fuel that had been irradiated sporadically in a low-power reactor (e.g., a few hours per week at a maximum power of 100 kw_{th}.) It is more difficult than separating the uranium from unirradiated fuel plates, but it is something that could be done with techniques that are widely published. If the safety rules are compatible with a high degree of military urgency to obtain the uranium for weapons purposes, then the fact that the fuel contained some fission products would not get in the way very much.

Furthermore, the fact that some of the HEU at research reactors might be in the form of irradiated fuel, either in the core or in storage holes, while other material was in the form of fresh fuel in separate storage, would be little if any deterrent to theft of all the material. Dose rates far in excess of what most NRC-licensed research reactors appear capable of routinely producing in their fuel bundles would be necessary, in my opinion, for the fuel to be "self-protecting." To cite one specific example, if the calculations in Dr. Roger Kohn's September 4, 1982, declaration in the UCLA licensing case are correct, fuel bundles in the UCLA reactor drop below 100 rem/hour (at three feet from any accessible surface without intervening shielding) after just 8 hours of shutdown, below 34 rem/hour after one day, and apparently down to a few rem per hour after a shutdown or storage period of a few weeks. If correct, and assuming that the reactor operates only a few hours per week, neither irradiated fuel in storage nor in the core would be self-protecting and would be little deterrent to dedicated individuals or groups intent on acquiring nuclear weapons material.

To assert that the 4000 to 5000 grams of uranium-235 at 93% enrichment in the form of uranium-aluminum flat plate fuel, which are authorized at this and seven other university research reactors, would be of no interest to someone intent on manufacturing a nuclear weapon would be simply incorrect. It is, in my opinion, a credible threat that people might break into such research reactor facilities in order to acquire HEU. Particularly if one supposes a blackmarket and people selling stolen HEU at, say, a hundred thousand dollars per kilo. At present, only three NRC-licensed university reactors are authorized to store less than four to five kilograms of uranium-235 in highly enriched fuels, while 12 are authorized to store larger amounts ranging up to 45 kilograms U-235.

It is my opinion that anything more than a kilogram would be clearly excessive. From a proliferation standpoint there should be a significant burden upon a university to demonstrate that it could not perform the functions for which the reactor was intended without the requested highly enriched uranium. I would say that even more broadly: highly enriched uranium should not be used in quantities of more than a few hundred grams under any circumstan es unless there is an absolutely compelling reason to do so. I know of no such reason that would be relevant to these reactors.

It is my opinion that the enrichment of these fuels is excessive. For general research use, the only advantage in going from 20% enriched uranium to 93% enriched uranium is that the neutron flux may increase somewhat at the same power level. I don't know what that increase in flux is for each specific reactor, but it is very hard to imagine that it would change significantly the nature of the experimental programs if the enrichment were reduced. Everybody wants to have all the neutrons they can get, but the universities already have limited themselves, by limiting the power of their reactors, and if they wanted more neutron flux they might increase the power level --- from 100 to 120 kilowatts, for example. One is talking about not anywhere near doubling the flux by increasing the enrichment.

Small kilogram quantities of uranium-235 in 93% enriched form would have, by far, greater potential consequences if stolen than an equal or even somewhat larger amount of uranium-235 in 20% enriched fuel. The critical mass of fully enriched uranium in metallic form with an ordinary reflector is roughly 20 kilograms. It depends on what the reflector is. With a more efficient reflector, the critical mass is considerably less. For example, critical mass with a thick reflector made of beryllium is approximately 11 kg. of uranium-235.

These figures are for the critical mass of uranium-235 at normal density. When compressed, the critical mass is considerably less. As I wrote in Nuclear Theft: Risks and Safeguards (Ballinger, Cambridge, Mass., 1974, at p. 20): "If, on the other hand the material is to be used in an implosion type of fission bomb, the amount required may be significantly lower than these quantities. Materials that are compressed above their normal densities have a lower critical mass than when they are uncompressed. In the special case when both the core and the reflector are compressed by the same factor, the critical mass is reduced by the square of that factor. Thus, when a spherical core and reflector assembly that is initially close to one critical mass is compressed to twice its initial density, it will correspond to about four critical masses." The maximum compression achievable in an implosion type fission weapon, and thus the minimum amount of uranium necessary to make such a weapon, depends upon the knowledge, skill, equipment and facilities of the bomb maker.

For 20% enriched uranium in metallic form with an ordinary reflector, the normal density critical mass of contained uranium-

235 rises to over 50 kg. It is possible to make a nuclear explosive with 20% enriched uranium but it would be very heavy, very inefficient and difficult to handle because of the relatively large amount of non-fissionable uranium 238 contained in this fuel. You would need approximately three times as much uranium-235 in the 20% enriched form as you would in the 93% enriched form in order to make a critical mass, but more important is the fact that you would be dealing with (three times five or) fifteen times as much uranium, which is much harder to move, much harder to compress.

Threats

The potential consequences of the theft of a single kilogram of 93% enriched uranium would be considerable if someone simply needed one kilogram to supplement an amount already obtained or if they needed or wanted some highly enriched uranium to make a threatened authority take a blackmail threat more seriously. To send a few grams would be so relatively easy to do that it might not have much effect on the credibility of the threat. To send a kilogram begins to be quite significant and they can simply say, "We haven't sent you more because, as you know, that is a significant fraction of the total amount we would need. We just want you to know we have kilogram quantities of this material and here is a kilogram."

Therefore, in my view, a request by an institution for kilogram quantities of highly enriched uranium is excessive unless there is some overriding reason that I cannot imagine --- such as national defense research, and even then I know of no such research which would require HEU fuel for such a reactor.

There is no crucial research at university reactors of which I am aware that would require weapons-grade uranium. I would say, in fact, that for uses of any kind, any quantity of HEU would be excessive. I say that because even in gram quantities there should be a special reason to have it because gram quantities could still be extremely helpful to people making a threat that might not necessarily be a hoax. It just reduces the amount of material they need in order to make a bomb, and also establishes credibility for a threat.

I have been informed that the original Argonaut reactor operated on 20% enriched fuel and that a number of other Argonauts have likewise operated on 20% enriched fuel. Assuming that is correct, I know of no reason --- and find it hard to imagine one --- why all Argonaut reactors should not likewise operate on 20% enriched uranium. I have also been informed that the University of Florida's Argonaut reactor was to be involved in testing some 4.8% enriched uranium oxide fuel. Assuming that that also is correct, that kind of fuel would likewise seem to me as something worth pursuing for other Argonaut reactors because it is even further away from weapons material.

I also have been informed that General Atomic currently has available low-enriched TRIGA fuel not only for conversion of TRIGA reactors, but for conversion of Argonaut and other research reac ors presently utilizing highly enriched MTR-type plate fuel. If necessary, I would view conversion of these non-TRIGA reactors to low-enriched TRIGA fuel as a favorable alternative to permitting their continued operation with highly enriched uranium. It is much more difficult to make weapons of any kind out of lower enrichment uranium; the compromises in neutron flux, which I think are the main concern, are not large, if present at all.

Safety

Besides significant safeguards advantages in making a conversion to low-enriched TRIGA fuel, there also would be significant safety benefits. There certainly was a major safety benefit in the TRIGA fuel when we designed it and the TRIGA reactor.[3] The main feature was a very strong prompt negative temperature coefficient, much higher than other research reactors, which meant that even if it went prompt critical the rise in temperature would extremely rapidly stop the chain reaction. That still stands. There is, of course, a level of excess reactivity above which the safety feature of not being able to damage any of the fuel with an accidental excursion is no longer true. You can always make it over-critical by design, to make it not have that self-limiting feature, but I don't see any excuse for doing it with any medium power research reactor, up to a megawatt at least.

The level of excess reactivity at which the prompt negative temperature coefficient ceases to be an effective self-limiting feature would be much higher for a TRIGA reactor or a reactor with TRIGA fuel than for the Argonaut and other research reactors operating with MTR-type fuel. At comparable levels of excess reactivity, the TRIGA fuel would definitely have significant safety advantages.

The difference in the TRIGA fuel is due to the fact that when the ratio of captures (in the water and other materials) to fissions (in the fuel) goes up, the reactivity goes down. That effect is produced by a change in temperature in the fuel itself, relative to the cooling water, and thus requires no heat conduction. It happens instantaneously because the heat is liberated by the fission reaction right in the fuel. In MTR-type research reactors the heat has to be transferred to the water, which takes a while, to make it expand. It is the expansion of that water plus some other effects that have to do with the water having to heat up that makes the reactivity go down. Because of this time-delay involved with the transfer of heat from the fuel meat to the water in MTR-type reactors, the shutdown mechanism is slower, permitting greater energy release before shutdown for an excursion of the same exponential period and a greater opportunity for fuel melting to occur before the excursion terminates than is true with the TRIGA.

That shutdown mechanism in the MTR-type reactors, requiring transfer of the heat to the water to cancel the reactivity, can produce effects in the water like boiling or a sudden expansion of the coolant which can, in effect, do some damage, even if fuel melting does not occur. The likelihood of there being changes in the fuel arrangement or in the grid supports or whatever is less for the TRIGA than for the Argonaut, according to the comparative designs when I knew about them. I was familiar with the Argonaut design at the time we designed the TRIGA.

In addition to the TRIGA fuel having a negative temperature coefficient that is far more prompt (i.e., it comes into play much faster), the size of the negative coefficient is also far larger, so the excursion is terminated much sooner, providing substantial additional protection against fuel melting.

The conversion to lower enriched uranium fuel, be it TRIGA fuel or flat plate fuel, would likely increase the negative temperature coefficient because of another factor, the Doppler effect. I cannot be absolutely sure there are not some compensating factors, but the Doppler broadening coefficient contribution to the temperature coefficient will go up and I do not know of any reason why other things would happen to make it go down.

A reduction in enrichment of the fuel can thus decrease the possibility or consequences of a destructive power excursion or criticality accident. Low enriched fuel has a contribution to limiting an excursion, an abating effect, that is the cancelling out of the reactivity because of the increased capturing by uranium-238. I cannot make the blanket statement that for any reactor design that it would be safer; it would be dependent upon a given change in the reactivity.

Security

Regarding what kind of security would be sufficient to satisfactorily minimize the risk of theft or diversion of kilogram quantities of HEU, consistent with the potential consequences of its theft, I would say that it should not be possible for a group quite knowledgeable about security and how to defeat it to describe to a jury of experts a credible scenario for stealing the material. In other words, I am thinking in terms of a jury situation, and I would say that security would be adequate if, and only if, such a jury of experts could not be presented with a theft plan that they thought had a reasonable chance of working.

I also would stress that an almost exclusive reliance on intrusion alarms tied into a campus police station absolutely would not be adequate, in my view, because that does not say anything about the ability of the campus police to effectively intercept people carrying out the theft. However, if there were an intrusion alarm between the point of entry and the material, and physical barriers in between sufficient to prevent penetration until the campus police and an additional response force had arrived on the scene, then I would say that would be effective. But by definition I am saying that something considerably more than an intrusion alarm is required --- that is, barriers, very heavy containers or the equivalent, something that would create a physical delay of some significance, to ensure getting protective people there. And when I say protective people, I do not mean simply one or two watchmen checking in, but a force capable of successfullly preventing the theft.

Any contention that detection of the theft or post-theft reporting woulk be sufficient is, in my opinion, highly irresponsible and not at all consistent with the potentially very significant consequences of theft of kilogram quantities of HEU. Merely being able to detect and report theft, while failing to adequately protect against theft, would be unconscionable.

I would view a theft of a kilogram or more of uranium-235 at 93% enrichment as having extremely significant potential consequences, simply by virtue of it being stolen. By this I mean it is then no longer a hypothetical question. When it has actually happened, it means that some people have gone to the trouble to steal that material. Having done so, it could be entering the black market, it could be joined with other materials which are on the blackmarket, it could go in the direction of being the start of the construction of weapons. I would say that if I heard a kilogram or more of highly enriched uranium had been stolen, I'd be extremely concerned. That would have international implications of great importance.

Conclusion

In conclusion, I would say continued use of highly enriched uranium in quantities of more than a few grams at domestic research reactors is highly undesirable and dangerous. The burden of proof should be on the reactor operators to make clear why it is truly necessary to use HEU as opposed to using 20% or less enriched uranium. I have not seen that case made. The essential consideration for the Nuclear Regulatory Commission is that highly enriched uranium is not essential to the operation of these reactors but is an essential ingredient for making nuclear weapons. The hazards of nuclear weapons being produced do not disappear even if the quantities of HEU at individual sites are not sufficient to make one nuclear weapon because these sources could be pooled.

It is very important for the Commissioners, in order to make rational decisions about the consequences of theft of uranium-235, to know what are the minimum quantities of uranium-235 necessary to make a nuclear weapon. I can say flatly that I would be very concerned about theft, clear evidence of theft, of a kilogram or more of highly enriched uranium, and I think everyone should be. If you ask how much less than a kilogram, I really could not go into that, and I want to make sure I am not being taken to say that one kilogram of highly enriched uranium is the minimum quantity necessary to make a bomb. That minimum quantity is not a well defined number at all. It depends on the talents, experience and requirements of the designers.

From the point of view of one who has designed nuclear weapons, a kilogram or more of 93% enriched uranium is certainly a significant quantity. There is no question about that. It should not be around in situations where theft could occur unless there is some vast overriding reason such as national defense, and I know of no such reason which could be remotely applicable to the reactors licensed by the NRC.

It is my opinion that HEU should be prohibited internationally. We have the mechanisms set up in the United States to work toward that objective. HEU should be prohibited except under conditions that I would say are extraordinary. The prohibition should come first and the exception should come later. No research facility should have a quantity of HEU sufficient for building a weapon under any circumstances for any purpose.

I note that the NRC, on August 24, 1982, issued a statement of policy committing itself to exercising its licensing authority to reduce, "to the maximum extent possible," the use of HEU in domestic and foreign research reactors (47 FR 37007). It appears to me very important that the NRC carry out that policy with regard to all research reactors and HEU under its direct control in order to set a domestic example that foreign regulators and operators of research reactors can follow. Such leadership by the Commission can also influence the policy and actions of the U.S. Department of Energy with regard to the far greater number of research reactors and far larger quantities of civilian HEU under its control.

Therefore, given what I know about what HEU can be used for in terms of construction of a nuclear weapon or making of a nuclear threat, and also based on what I know about the needs of research reactors, the Commission should promptly issue a rule requiring the use of fuel of a lower enrichment. I would say further that every institution now using research reactors should look very carefully at the risks versus the benefits obtained (and the risks are significant) and treat them as potentially very dangerous pieces of equipment. The danger is especially worrisome when there are kilogram or more quantities of nuclear materials from which nuclear weapons can be made. The whole institution, not merely the nuclear engineering department, should make that assessment. My advice for them would be to avoid having reactors unless you absolutely have to. If you must have a reactor, always use the lower enrichment and keep the lowest quantity of uranium on hand. I doubt that there is any crucial research at a university requiring weapons-grade uranium.

FOOTNOTES

1. See also my declaration dated December 16, 1982, before the Atomic Safety and Licensing Board considering the license-renewal application of the UCLA Argonaut research reactor (Docket No. 50-142).

2. One such simple method is described on page 97 of John McPhee's The Curve of Binding Energy, Random House, NY, 1973, 1974.

3. A good description of the origins, intent, and basic operating principles of the TRIGA and its fuel can be found in Freeman Dyson's Disturbing the Universe (Harper & Row, NY, 1979), pgs. 94-102.

Professional Qualifications

DR. THEODORE B. TAYLOR

My name is Theodore B. Taylor. I am Chairman of the Board of Nova, Inc., a technical consulting firm specializing in energy applications.

I received my B.S. degree in physics in 1945 from the California Institute of Technology and my Ph.D. degree in theoretical physics from Cornell University in 1954.

From 1946 to 1949 I worked as a theoretical physicist at the University of California Radiation Laboratory in Berkeley.

From 1949 to 1956 I was on the staff of the Los Alamos Scientific Laboratory, working on the design of nuclear explosives. One of my primary assignments at Los Alamos was to design fission bombs of very small physical dimensions and mass.

In 1956 I joined the General Atomic Division of General Dynamics Corporation where, along with Edward Teller, Freeman Dyson, and others, I helped design the TRIGA research reactor. While at General Atomic I was also technical director of the Nuclear Space Propulsion Project (Project Orion).

From 1964 to 1966 I was deputy director (scientific) of the Defense Atomic Support Agency, U.S. Department of Defense.

I spent the following two years in Vienna, Austria, as an independent consultant to the U.S. Atomic Energy Commission and several other organizations, working on the subject of international safeguards for nuclear materials.

In 1967 I founded the International Research and Technology Corporation, a company primarily concerned with studies of the impact of technology on society, which I served as Chairman of the Board until 1976.

From 1976 to 1980 I was Visiting Lecturer with rank of Professor in the Mechanical and Aerospace Engineering Department at Princeton University.

In the aftermath of the accident at the Three Mile Island nuclear power plant, I served as a Commissioner on the President's Commission on the Accident at Three Mile Island (the "Kemeny Commission.")

I am a member of the American Association for the Advancement of Science and the American Physical Society, a member

of the Board of Directors of Nuclear Control Institute, and have served as a consultant to the Air Force Science Advisory Board, 1955-58, Los Alamos Scientific Laboratory, 1956-64, Aerospace Corporation, 1960-61, Atomic Energy Commission, 1966-70, Defense Atomic Support Agency, 1966-69, Rockefeller Foundation 1977-79, and was chairman of the Los Alamos Study Group, Air Force Space Study Commission, 1961.

In 1965 I was one of the recipients of the Ernest C. Lawrence Memorial Award of the AEC for work on the development of nuclear explosives and the TRIGA research reactor.

I am co-author of The Restoration of The Earth (1973), Nuclear Theft: Risks and Safeguards (1974), Energy: The Next Twenty Years (1979), and author of numerous articles on nuclear safeguards and proliferation in technical journals and popular media. A more detailed account of my activities in the safeguards field can be found in John McPhee's book, The Curve of Binding Energy (1973, 1974).

I maintain an active "Q" clearance.

Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

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ISSUE BRIEF

The Use of Atom Bomb Material in Civilian Research Reactors

Highly enriched uranium* (HEU), a nuclear-weapons material, is also used as fuel for many research reactors throughout the world. While concerns over the proliferation of nuclear weapons have focused primarily on plutonium, a byproduct of power reactors that can be used in weapons, the use of HEU in civilian research represents a more immediate threat to international security. The issue of HEU use is now at a critical point because the Nuclear Regulatory Commission (NRC) has proposed a rule to require those research reactors it licenses to convert from HEU to lower-enriched uranium unsuitable for weapons. As virtually the exclusive supplier of HEU for research reactors throughout the world, the United States is in a position to take the lead in discontinuing its use.

The Dangers of HEU

There are currently 137 research and test reactors in 34 countries which use HEU as fuel. More than a third of these reactors (45) are in the United States. According to data from the Energy Department, the annual requirement of U-235, the fissile isotope contained in HEU (see note below), for the world's reactors is over one metric ton of which the United States provides 99 percent. There are 4000 kilograms in circulation at any one time -- enough for at least 205 atomic bombs on the basis of a conservative estimate of 20 kilograms per weapon.

The United States has exported some 23,590 kilograms of HEU (containing 16,980 kilograms of U-235) to 43 nations from the start of the Atoms for Peace program through 1982, according to data assembled by David Albright of the Federation of American Scientists (see table and graph). Currently, the United States is exporting about four to five hundred kilograms of this bomb-grade material each year. There have been, however, a number of years when the exports far exceeded this current annual demand.

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*Highly enriched uranium is uranium that has been enriched in the fissile isotope U-235 from the naturally occurring level of slightly less than one percent to as high as 90 percent for use in weapons and research reactors.

Although the amounts of HEU at many of the smaller domestic and foreign research reactors are usually below the 20 kilogram quantity often cited as necessary for a weapon, they still pose an unwarranted proliferation risk. Dr. Theodore Taylor, a former nuclear weapons designer and a member of the board of Nuclear Control Institute, stated at a recent meeting of the NRC that the existence of even one or more kilograms of HEU in civilian research programs is extremely dangerous:

> It is very important for the Commissioners, in order to make rational decisions about the consequences of theft of uranium-235, to know what are the minimum quantities of uranium-235 necessary to make a weapon. I can say flatly that I would be very concerned about theft, clear evidence of theft, of a kilogram or more of highly enriched uranium, and I think everyone should be. From the point of view of one who has designed nuclear weapons, a kilogram or more of 93 percent enriched uranium certainly is a significant quantity.

One of the reasons cited by Dr. Taylor for being concerned about kilogram quantities of HEU is the possibility that stolen material will be used in an implosion type of fission device which radically decreases the amount necessary for an explosion. Dr. Taylor, who in addition to being a weapons designer also designed one of the most commonly used research reactors (the TRIGA) throughout the world, stated that he could see no reason for HEU to be used as a reactor fuel under any circumstances. He asked that the "national benefits" of HEU be weighed against the risks of theft or diversion before any exception is made.

Despite the weapons implications of even small quantities of HEU, the methods used to protect and track the material are often extraordinarily weak. The principal factor contributing to lax security at the smaller reactors in the United States is that most are owned and operated by universities reluctant to institute security measures that are expensive and inappropriate to a university environment. Numerous instances of such security problems as lost keys, defective alarm systems, open access to sensitive areas and the storing of HEU in filing cabinets have been documented by Daniel Hirsch, President of the Committee to Bridge the Gap. The NRC security requirements for university reactors are far from rigorous, and the Commission is not disposed to press the universities too hard on infractions.

The United States has also had trouble tracking and assuring the physical security of the HEU which it sends abroad. In a report issued in August of 1982, the General Accounting Office found that "[t]he Department of Energy's central computerized system used for tracking all U.S. highly enriched uranium exported to foreign countries is incomplete and inaccurate." According to the GAO, the various tracking systems are not coordinated and each system only provides one segment of the overall picture, making it impossible to establish an accurate inventory for each country.

The GAO also found that U.S. officials assigned the task of assessing physical security arrangments have had trouble gaining access to foreign facilities using U.S. HEU and that intervals between visits have become lengthy. Also, a program instituted in 1968 to take back spent HEU fuel (which is still weapons useable) has been largely unsuccessful and only a small percentage of the fuel has been returned.

Efforts Toward a Solution

With increased awareness of the dangers of nuclear proliferation in the wake of the Indian explosion, a consensus developed that the use of HEU in civilian research programs presents an unwarranted proliferation risk and should be discontinued in view of the feasibility of converting to low enriched fuels. The summary report of the International Fuel Cycle Evaluation (INFCE, 1980) stated that it is feasible to markedly reduce the enrichment of a great majority of research reactors and endorsed the conversion of HEU-fueled research reactors to lower enrichment.

In 1977, the United States announced a nuclear non-proliferation initiative to significantly reduce U.S.-supplied inventories of HEU and announced plans for a research program to develop low enriched (20% U-235 or less) alternative fuels. The Reduced Enrichment Research and Test Reactor (RERTR) Program has been successful in developing low enriched fuels suitable for virtually all of the world's research reactors.

In 1981, Representative Ed Markey (D-Massachusetts) introduced an amendment to the NRC Authorization Bill to ban HEU exports altogether. The amendment was rejected because most Members were persuaded that the United States would phase out HEU exports as soon as new fuels became available through the RERTR program.

Foreign recipients of U.S. HEU generally have been supportive of the conversion program but also want assurance that the United States will stop using HEU as well. At the last annual international meeting in Japan of those concerned with the conversion program, the issue of "even handedness" by the United States was raised at a roundtable discussion. NRC Commissioner Victor Gilinsky told the meeting that the NRC "intends to demonstrate that conversion to low enriched fuel is not a difficult process by taking steps to enable domestic reactors operating in the United States to convert to low enriched fuels," and he cited the NRC's proposed rulemaking on HEU-use. Foreign reactor operators and their governments are waiting, however, to see whether the U.S. conversion actually is put into effect and how extensive it will be.

In August of 1982 the NRC issued a policy statement (47 FR 3006-3007) strongly supporting the RERTR program and announcing its interest "in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors." The statement concluded with this key paragraph:

> The commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. reactor operators.

Operators of NRC-licensed research reactors, however, recommended that the policy apply only to new reactors and to new fuel purchases. This approach at first received considerable support from the NRC staff, which recommended that the Commission adopt a limited conversion rule.

The problem with such a rule was that it would affect only the few larger reactors that require regular reloadings of HEU fuel. Most research reactors have a lifetime supply on hand. No new reactors are likely to be built any time soon. The NRC policy statement would have been gutted.

On January 27, the Commission heard from a panel of experts assembled by Nuclear Control Institute, as well as from nuclear-weapons, safeguards and proliferation specialists from a number of Federal agencies. The Commissioners' primary concern was that a comprehensive rule would cause an unacceptable financial burden on the universities. Many of the universities claimed that the costs of conversion would force them to shut down the reactors unless monetary aid was forthcoming.

On July 6, the Commission issued a proposed rule requiring the conversion of all research reactors under its jurisdiction, assuming the availability of financial support to cover the costs of conversion. Congress then appropriated $2 million toward the first-year costs of conversion. Exceptions to conversion can be made for larger reactors for which LEU fuel is not yet available or for reactors the Commission finds have a "unique purpose" necessitating continued use of HEU.

The cost of university reactor conversion (estimates range from $5 to $15 million) amounts to only 8 to 25 % of the total to be spent on developing the new fuels. In addition to the 24 HEU-fueled university research reactors, there are one government and four corporate HEU-fueled reactors, licensed by the NRC.

The Reagan Administration and HEU

A strong final NRC rule can set an important example with regard to converting research reactors at home and abroad, but the ultimate success of a conversion policy depends on the actions of the Reagan Administration. Although the RERTR Program has been largely successful, it has received less than enthusiastic support from certain quarters within the Department of Energy (DOE), the lead agency for the program.

The GAO, in its 1982 report, found that in 1981 the program's funding had been reduced to a fraction of what it had been the year before. Since that time funding has been gradually increased, but it has taken three years to reach levels set by the previous Administration. Even now there are signs of a continuing struggle by proponents of the program to gain adequate funding.

DOE's operation of its own research reactors is a key HEU policy area. Although fewer in number than the NRC-licensed research reactors, the civilian DOE reactors account for 90 percent of the annual domestic civilian consumption of HEU. DOE is using one reactor (the Oak Ridge Reactor in Tennessee) to test fuels for RERTR but it has made no commitment as to converting the others. Foreign purchasers of U.S.-HEU fuel would most like to see the high power DOE reactors convert at the same time they convert their reactors. If the DOE reactors are not converted, foreign reactor operators may simply seek out non-U.S. suppliers of HEU and the conversion effort could collapse.

Ultimately, a successful U.S. effort to achieve an international ban on HEU use depends upon the Department of State. Even a full-scale domestic conversion will have little affect abroad if State fails to follow through by making conversion of overseas reactors a high priority foreign policy goal. Unfortunately, Richard Kennedy, the U.S. Ambassador-at-large for non-proliferation, in a letter to NRC Chairman Nunzio Palladino commenting on NRC's HEU policy, indicated that the original weak rule proposed by NRC staff would be compatible with the State Department's objectives:

> The proposed rule for conversion of domestic research and test reactors calls for replacement of spent HEU fuel with low enriched fuel, "if such action would be technically feasible with existing fuel technology at the time of refueling, and unless the licensee shows that the unique purposes of the project could not be achieved without using HEU fuel," would be compatible with the criteria used for establishing conversion feasibility and schedules in cooperation with foreign reactor operators.

The statement suggests that the State Department is not prepared to seek conversion of low-power foreign reactors with lifetime supplies of U.S. HEU fuel and is even willing to allow exceptions for continued HEU exports.

In his letter to Palladino, Kennedy stated that NRC's domestic rule would have only a "marginal benefit" for the State

Department. This suggests State Department concern that the NRC might be taking a harder line against HEU use than the United States is seeking abroad.

A Problem That Can Be Solved

There are many technically complex and politically difficult issues to contend with in seeking to prevent the proliferation of nuclear weapons, but the use of highly enriched, weapons grade uranium as fuel for civilian research reactors stands out as one problem that can be solved with relative ease. In contrast to the seemingly insurmountable technological barriers to achieving effective controls on some sensitive nuclear materials and technologies, the RERTR Program provides a readily achievable solution. Although many U.S. non-proliferation initiatives meet with stiff resistance abroad, the U.S. objective of phasing out exports of HEU in conjunction with cooperative efforts to convert research reactors to low enriched fuel has been received surprisingly well by foreign reactor operators and their governments.

Considering the impressive progress made by the RERTR program in developing alternative low-enriched fuels, the political costs to U.S. foreign policy of pushing for a complete ban and moving toward a moratorium on exports should not be that great. Even high-power research reactors can be converted to low-enriched fuel if the operators and their governments become convinced that the reduction in performance characteristics is an acceptable price to pay for the greater security achieved. DOE should be prepared to set an example with regard to its own high power research reactors.

In addition, the State Department should be working to retrieve all the HEU at low-power foreign reactors that have lifetime supplies on hand. Some of these reactors would continue to use HEU for 20 years or more even with a ban on U.S. exports unless the fuel is returned for the low-enriched alternative. A strong NRC rule with respect to equivalent U.S. reactors would help the State Department to achieve the return of lifetime cores of HEU.

If HEU fuel is not essential for research and if no further production of HEU is required for the weapons stockpile or for naval propulsion fuel, as may well be the case, the basis would be established for suspending further production of HEU and even for blending down existing HEU stocks into low enriched uranium for use in civilian research and power programs.

Exports[a] of HEU From 1954 Through 1982

Country	HEU (kg)[b]	Contained U-235 (kg)[b]	% U-235 (average)
Argentina	94	59	63
Austria	9.8	7.3	75
Australia	10	9.2	90
Belgium	187	159	85
Bolivia	c	c	-
Brazil	7.7	7.2	93
Canada	1,861	1,724	93
Columbia	3.1	2.8	90
Czech.	c	c	-
Denmark	26	24	92
Finland	3.9	.77	20
France	6,268	4,655	74
W. Germany	9,990	6,611	66
Greece	6.6	6.1	93
IAEA	.31	.25	81
Ireland	c	c	-
Indonesia	.018	.13	72
India	.098	.081	83
Israel	19	17	90
Iran	5.5	5.2	93
Italy	382	307	80
Japan	1,995	946	47
Korea	30	18	62
Malaysia	c	c	-
Mexico	30	12	42
Netherlands	63	57	89
Norway	.01	.008	80
Pakistan	5.8	5.2	90
Philippines	3.3	3.1	93
Portugal	7.7	7.2	93
Romania	39	37	93
South Africa	33	30	92
Spain	9.4	8.3	88
Sweden	148	133	90
Switzerland	8.8	8.0	91
Taiwan	9.9	9.2	93
Thailand	5.3	4.8	90
Turkey	5.3	4.8	90
U. Kingdom	2,301	2,141	93

(Table continued on back)

Country	HEU (kg)[b]	Contained U-235 (kg)[b]	% U-235 (average)
Uruguay	c	c	-
Venezuela	.011	.009	82
Vietnam	.39	.08	21
Yugoslavia	17	5.9	35
Zaire	1.4	.28	20
Total	23,590	16,980	72

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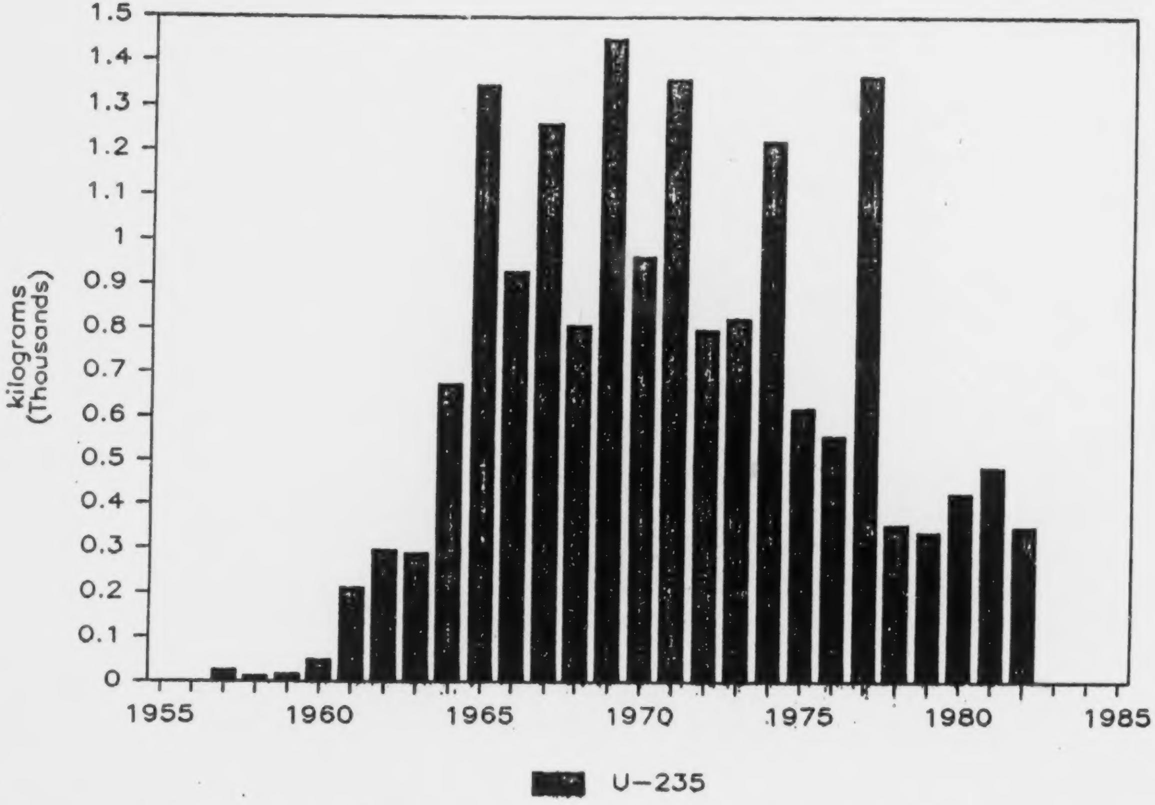
a. Figures represent shipments by U.S. to foreign countries. Returns to U.S. and retransfers to other foreign countries are not reflected in the data.
b. Amounts rounded off
c. A few grams at most.

Source: Department of Energy, Nuclear Materials Management and Safeguards System

Table prepared by David Albright, Federation of American Scientists

ANNUAL U.S. EXPORTS OF U-235



GRAPH PREPARED BY DAVID ALBRIGHT, FEDERATION OF AMERICAN SCIENTISTS

SOURCE: DEPT. OF ENERGY

October 12, 1984

STATEMENT OF

STEPHANIE A. MURPHY
NUCLEAR TERRORISM RESEARCH PROJECT
ADLAI E. STEVENSON PROGRAM ON NUCLEAR POLICY
UNIVERSITY OF CALIFORNIA AT SANTA CRUZ

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY
ENERGY DEVELOPMENT AND APPLICATIONS SUBCOMMITTEE
AND
ENERGY RESEARCH AND PRODUCTION SUBCOMMITTEE

U.S. HOUSE OF REPRESENTATIVES

My name is Stephanie A. Murphy. I am a researcher focusing on issues of terrorism and the threat terrorists pose to safety and security in the United States through assault on or theft from nuclear facilities. Although my research has been conducted in conjunction with the Nuclear Terrorism Research Project of the Adlai E. Stevenson Program on Nuclear Policy at the University of California at Santa Cruz, the views expressed here are my own and not necessarily those of the University of California.

Introduction

In the past decade, data on terrorist trends have increasingly indicated a growing necessity to safeguard nuclear facilities against actions by terrorists. Since 1972, international terrorism has taken on a heightened level of violence and frequency. The latest example of this trend has been the rash of embassy bombings in Beirut which have resulted in over three hundred deaths. The recurrence of the truck bomb attacks underline the vulnerability of U.S. facilities, especially politically symbolic ones, and indicate an increased risk for facilities at home.

Coinciding with increases in terrorist violence and the numbers of deaths caused per incidence has been a ten-fold increase in the number of nuclear-related incidents since the early 1970s. Though terrorists have apparently not yet acquired an atomic bomb nor used one, an act of nuclear violence could well be the next step in the trend of escalating terrorist activity.

The 1981 Israeli destruction of Iraq's Osirak research reactor, fueled with highly enriched uranium (HEU), broke through a psychologically important barrier by making nuclear facilities targets. Although the Israelis have said the attack was carried out to prevent the Iraqis from acquiring a nuclear bomb, the act may well have had the unintended additional effect of relaxing existing constraints on terrorists regarding nuclear violence. The destruction of the research reactor may well have established new political battlefields for terrorist activity.

Clearly, we have entered a new era involving a wider variety of terrorist threats. The embassy truck bombings in Beirut indicate that terrorists are willing to carry out attacks with the knowledge that the action will result in their own deaths. This, in conjunction with increased nuclear-related terrorism and the destruction of the Osirak research reactor, presents a horrifying picture of possible future actions.

At a time when terrorist violence is increasingly aimed at the United States and the terrorist desire for or the use of a nuclear capability is increasing in likelihood, it is absolutely necessary to provide for effective safeguards against this potential threat. Research reactors containing highly enriched uranium (HEU) would be a prime target for these acts by providing terrorist groups the opportunity to acquire bomb-grade uranium with relative ease. Research reactors are known to be significantly less protected than such Department of Energy weapons facilities such as the Los Alamos National Laboratory, yet the extent of even Los Alamos' ability to defend against nuclear theft was recently called into serious question in a series of safeguards tests in which it failed three out of three tests. In each case at Los Alamos, terrorists would have been able to successfully steal either weapons-grade materials or even a fully-assembled nuclear bomb. In this light, it is clear that HEU is presently not safe in the far-less-well protected research reactors.

Because many research reactors are at universities, it would be difficult to sufficiently upgrade safeguards to adequately protect against theft of HEU while maintaining a normal academic environment. The use of low enriched uranium (LEU) is thus a logical preventive step against terrorist assault and theft. The conversion to LEU would greatly reduce the terrorists' incentive for theft and would make research reactors less likely targets of terrorist attack.

Nuclear Terrorism

Nuclear terrorism can be viewed as a subset of terrorism, adhering to many of its tendencies and traits. Several character traits can be noted which are extremely important when considering terrorism in the nuclear sphere. A typical terrorist action carries with it not only the physical effects (e.g. kidnapping, bombing, embassy siege), but also a larger symbolic effect surrounding the object of the act itself (e.g. bombing on a national holiday, etc.). Traditionally, it is this symbolic impact that draws the public attention and presumably nets results, be they monetary, political, or simply increased terror and publicity itself.

Recently there have been reports written on the incidence of terrorism and the likelihood of increased and potentially catastrophic incidence of nuclear terrorism. Several of these reports[1] were prepared for the Rand Corporation by Brian Jenkins, who defines[2] terrorism as:

> An act by an organized group with some kind of political objective, usually directed against civilian as opposed to military targets, usually a group that claims responsibility; it's carried out in a way to achieve publicity, and it's intended to produce psychological effects beyond the immediate physical effects.

In light of the deadly nature of nuclear materials, one must examine in some detail the rapidly changing nature of terrorism.

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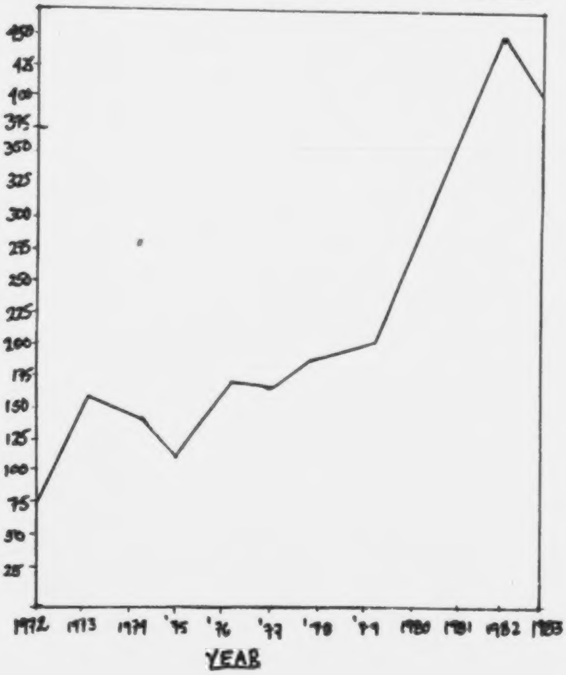
1 "Motivations and Possible Actions of Potential Criminal Adversaries of U.S. Nuclear Programs," January 1981, Rand Corp.; "The Appeal of Nuclear Related Crimes to the Spectrum of Potential Adversaries" February 1982, Rand; "A Review of Recent Trends in International Terrorism and Nuclear Incidents Abroad", April 1983, Rand

2 interview in San Francisco Chronicle, April 22, 1984

Increased Incidence and Magnitude of Terrorist Violence

Recent trends in terrorism indicate a weakening of moral and political constraints which some scholars had previously hoped would prevent terrorists from carrying out acts which could result in very large casualties. In general, the new data indicate an increase in numbers of terrorist incidents, numbers of casualties, and numbers of nuclear-related incidents. Figure 1 shows graphically the dramatic increase in terrorist incidents in the last decade or so, with the steepest rise in the last few years.

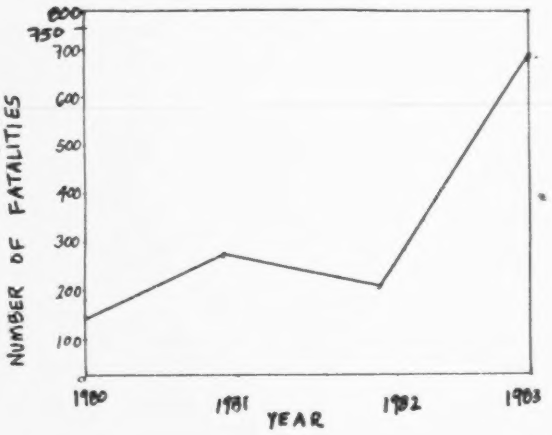
Figure 1. Number of Terrorist Incidents



source: "A review of Recent Trends in International Terrorism and Nuclear Incidents Abroad", Rand, April 1983; 1982 and 1983 Rand incidents figures from San Francisco Chronicle, April 22, 1984

There has also been a significant escalation in the form that terrorist violence has taken since the mid-1970s, with terrorist activity becoming more sophisticated as well as demonstrating a willingness to kill ever greater numbers of people. This new scale of violence can be tracked through the 1972 Munich Olympics, to the attempts (twice successful) to shoot down airliners with ground-to-air missiles in Rhodesia during the late 1970s, to the recent truck bombings in Beirut. Statistics show that the number of fatalities in terrorist incidents are increasing dramatically. The number of incidents with fatalities increased during the 1970s and into the 1980s. The number of fatalities doubled from 1980 to 1981, and more than doubled again in 1983. (See figure 2).

Figure 2. Number of Fatalities



source: "A Review of Recent Trends in International Terrorism and Nuclear Incidents Abroad", Rand April 1983;
1983 and 1983 Rand fatality data from SF Chronicle, 4/22/84

Nuclear-related terrorist incidents also escalated from an average of 1.5 incidents per year in the 1966-76 period to 27 incidents in 1979 alone, 26 in 1980, and 21 in 1981. See table 1, next page.

Table 1

NUCLEAR INCIDENTS ABROAD: 1966-1981

Tactic	Year 1966	1968	1973	1974	1975	1976	1977	1978	1979	1980	1981	Total
Bombings					5	2	4	5	10	13	15	54
Diversion, unauthorized use[a]		1			1				1	1		4
Theft	1			1					1	1		4
Sabotage, arson							2	3	4	2		11
Extortion, threats									1			1
Insiders												0
Assaults			1				2	2	2	1	5	13
Intrusion, trespass									2	1		3
Illegal trade								1				1
Miscellaneous thefts					1		3		1			5
Malevolent use[a]				3					2	1		6
Unauthorized disclosure									2	1		3
Disruption of transport[a]									1	3	1	5
Occupation of facilities												0
Standoff attacks												0
Other							1			2		3
Total	1	1	1	4	7	2	12	11	27	26	21	113
No. of fatalities	0	0	0	0	0	0	2	2	1	2	2	10

[a] Of nuclear materials.

source: "A Review of Recent Trends in International Terrorism and Nuclear Incidents Abroad", Rand 1983; 1982 data not included because incomplete

One potential threat of nuclear terrorist activity comes from the employees of the facilities. In this country, there have already been numerous attempts at sabotage and demonstrated thefts by employees at nuclear facilities. In 1979, the General Electric plant in Wilmington, North Carolina received an extortion letter demanding $100,000 in cash, threatening to disperse a container of uranium oxide powder throughout a large, unnamed American city. The letter contained a sample of the UO_2, and the writer said he possessed two five-gallon containers of it, which he identified by the plant's serial numbers. The General Manager of the plant verified the fact that the containers were missing.[3]

In another instance, two employees of a Surry, Virginia plant poured sodium hydroxide (lye), a strong corrosive agent, on new fuel assemblies being stored at the plant. Both had authorized access to the storage building.[4]

The insider with access to virtually every area of a nuclear facility could play a potential role in aiding political groups to attain their desired results.

Deteriorating Political Constraints

It is in light of the dramatic increase in terrorist violence and a demonstrated trend toward theft, sabotage of and threats to nuclear facilities, that one should view world political events and evaluate the existing political constraints. In 1981, with the incidence of terrorism then at its highest, the Israeli government bombed and destroyed Iraq's Osirak nuclear research reactor, then under construction. The bombing, marking the first time a nuclear reactor had actually been destroyed, could have a powerful impact on deteriorating political constraints. The attack, the Israelis have stated, was a response to their believe that Iraq would attempt to divert weapons-grade nuclear material and technology from their research reactor for use in making atomic weapons, an event the Israelis say they could not, in their national interest, permit. There were attempts made to stop the Osirak project prior to the Israeli destruction of the reactor in 1981. These attempts included bombings of facilities in Rome and France, where components for Osirak were being developed, as well as the murder of an Egyptian nuclear scientist who was working as the technical link for the installation and operation of the Osirak reactor. Though denied by Israel, there has been widespread speculation that the destruction of some of the reactor's components was carried out by agents of the Israeli government.[5]

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[3] "Potential Threat to Licensed Nuclear Activities from Insiders," NUREG-0703 (Nuclear Regulatory Commission), July, 1980.

[4] Ibid.

Nine months before Osirak was finally destroyed, Iranian fighter-bombers attacked, but failed to damage the reactor. (During neither air attack was the reactor yet radioactive.) This bombing, as strategy in the conflict between Iran and Iraq, marked the first time a nuclear facility had been targeted during wartime.

The final destruction of the Osirak reactor has set a major historical precedent. A research reactor with highly enriched uranium and believed to be capable of producing plutonium was the target of attack. Research reactors utilizing weapons-grade uranium or producing substantial amounts of plutonium may now become far more likely targets of attack in this era of changing terrorist violence.

Deteriorating Moral Constraints

Just as political constraints are loosening, so too are apparent moral constraints. Though in the past some scholars have though that terrorist groups would abide by a common set of moral constraints, restricting themselves to high-visibility but low-casualty scenarios, recent events give reason to believe times are changing.

In the past, wanton terrorist killing has provoked general condemnation and has placed some degree of restraint upon groups. The Basque terrorist group, Euzkadi Ta Azkatasunia or ETA, however, has pressed these moral limits. The ETA is one of the most radical groups active in opposing a nuclear plant, although they do not act for anti-nuclear reasons. The group, a separatist organization for Basque Homeland and Liberty, opposed the construction of two reactors at Lemoniz, because it is part of the Basque region. The group sees the reactors as being forced upon them by an illegitimate government. The group used tactics such as bombings, killings and attacks on powerlines and industries producing components for the reactors. Top plant officials were murdered and the lives of all workers involved in the plant's construction were threatened. These actions succeeded in stopping the construction of the Lemoniz plant.

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[5] Rand, 1983, ibid., p. 70-71.

The particular methods used and their success in achieving their goals is indicative of changing moral contraints on terrorist groups. Although their methods initially elicited great public outrage, the ETA persisted with their activities until public fear and outrage actually aided them in achieving their goals. This may suggest to other terrorist groups that to persist despite public revulsion will earn political success.

Public moral outrage is therefore no longer an effective response to extreme tactics; in fact, this outrage has become a means by which terrorist groups can achieve their goals.

The embassy truck bombings in Beirut have also demonstrated severely reduced moral constraints on terrorists. The truck bombing in October of 1983 which killed more than 250 people at the U.S. Marine Compound represented the largest loss of U.S. military lives since the Vietnam war. Not only is the terrorist tendency now toward killing large numbers of people, but the kamikaze style of these attacks represents heightened furor or a decreased expected rationale on the part of the terrorists. Moral restraints acting on terrorists have been replaced by conviction for a cause, even though their resulting death may net only a symbolic success for their group. One can no longer assume, therefore, that public outrage will in any way deter the terrorist, as these individuals do not even value their own lives.

The suicide truck bombings are especially insidious; the terrorist's willingness to take his/her own life makes protecting against attack extremely difficult. After the October 1983 bombing, the Secretary of Defense, Casper Weinberger admitted, "Nothing can work against a suicide attack like that, anymore than you could do anything about a kamikaze flight diving into a carrier in World War II."[6]

After three truck bombings the U.S. appears helpless to defend itself against new terrorist methods. It was only after each incident in Beirut that the United States realized its gap in safeguards--in the nuclear arena, the magnitude of the damage possible is dramatically increased. Neglecting to assess and upgrade safeguards until after a disaster would be appalling irresponsible.

Evaluating Safeguards--"...a shambles"

If an increasing tendency toward nuclear terrorism is taking place, it is then necessary, and only logical, to evaluate and upgrade the facilities' safeguards as they would be the target or source of future terrorist actions. The facilities must be able to guard against group assaults or insider-aided theft. Security measures at nuclear facilities are infamously insufficient; the facilities often have large quantities of material unaccounted for (MUF) and inexperienced or insufficiently trained security guards. A recent test of security forces at one plant timed security response to a mock attack. The officials responded 16 minutes after the would-be attackers had left with the plutonium. Security alarms and sensors failed to work in other test conditions. Research reactors, particularly those at universities, have vastly less security that the Los Alamos National Laboratory, yet LANL failed three out of three tests conducted.[7] In two tests the mock terrorists would have been able to make off with plutonium and in the third they would have been able to steal a fully assembled test device (an unlocked nuclear explosive)--a situation which Congressman Dingell termed "a shambles." These tests resulted in the closing of Los Alamos' "S" site because of the inadequate security.

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[6] Time, November 7, 1983

[7] May 7, 1984, letter, Dingell to DOE Secretary Hodel

Obviously, steps must be taken to secure weapons-grade material at university research reactors which have vastly less security than a national weapons lab such as Los Alamos.

Ineffective Response to Theft

There have been 70 nuclear extortion threats in the U.S., each of which has, because of facilities' large quantities of material unaccounted for, been taken seriously.[8] The government's nuclear emergency search team, NEST, has been called in on 20 of these threats, and would be the government's major recourse to the theft of HEU.[9]

However, as this country's most organized system of response to a nuclear threat, NEST is most inadequate. NEST basically consists of five helicopters with radiation detectors that are dispatched from heliports in Las Vegas and Andrews Air Force Base in Washington, D.C. to the area of the threat's origin. The helicopters "comb" the area in search of radioactivity, a process which in cities takes days. Granted that NEST has highly trained experts at its fingertips who, through lab analyses of extortion notes, glean information on the mental condition of the writer, and his/her sex, age, and level of education; however, none of this prevents a threat from actually being carried out. Analysts can aid in detection of the threat's veracity, but this will not speed the process of detecting the source of the threat. Depending on the sanity of the individual or the seriousness of a political group's willingness to kill many people and destroy a city, a bomb could be detonated before the helicopters have located it.

There is also some question as to the length of time required for NEST to reach the threat's site from its bases. Though NEST is ready to deploy in two hours, the threat's site may be a great distance from NEST heliports.

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[8] U.S. News and World Report, February 7, 1983

[9] Ibid.

Conclusion

If research reactors continue to use HEU, it is clear that they must be strictly and thoroughly protected against the rising risks of nuclear theft and assault. The existing safeguards at research reactors are not sufficient to prevent theft. Neither is the government's search team, NEST, an effective after-the-fact response. Because many research reactors are at universities, it would be difficult to retain an academic research and teaching environment if security measures were sufficiently increased. Additionally, the cost of the necessary security measures would far outstrip the costs of conversion to non-weapons-grade fuels. Even with such security, the university would remain a likely target because of the continued presence of HEU at the facility.

Conversion to low enriched uranium is the logical option in providing a greater level of security by removing the incentive for theft. Conversion would be less costly than the high level of security needed to guard HEU for the life of the reactor; neither would conversion hinder research in any way, as reactors function as well on LEU. In fact, it would be more conducive to the scientific research atmosphere, being less a terrorist target for theft or destruction.

The chief concern for these facilities must be their safety and security; ignoring political warning signs can only net disaster. The past four years have seen the destruction of a HEU-fueled research reactor in Iraq, and escalated levels of terrorist violence, both nuclear and non-nuclear related, especially directed toward the U.S. We have also witnessed the U.S. as a three-time victim of suicide truck bomb attacks, against which our Secretary of Defense has stated it is impossible to protect. These events would appear to be a mandate to protect our facilities against a terrorist attack. Conversion to LEU is the logical choice, being both far safer and less costly to protect than HEU. The failure to use foresight on this matter could have catastrophic effects.

SOUTHERN CALIFORNIA FEDERATION OF SCIENTISTS
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Statement of Dr. Sheldon C. Plotkin
Co-Chairperson, Southern California Federation of Scientists

Before the
Subcommittee on Energy Research and Production
and the
Subcommittee on Energy Development and Applications
of the
House Committee on Science and Technology

October 11, 1984

My name is Dr. Sheldon C. Plotkin. I am an engineer by profession, and Co-Chairperson of the Southern California Federation of Scientists, a thirty-five year old organization of scientists and engineers. SCFS has, for the last five years, been deeply involved in issues regarding safety and safeguards at research reactors. We strongly support the proposed NRC rule to require such reactors to convert to the use of non-weapons-grade nuclear fuels. Should the rule be reversed, two serious consequences could result: major obstacles to achieving the U.S. foreign policy goal of converting foreign reactors and thus reducing commerce in weapons-usable materials, and the potential for theft and possible detonation of Highly Enriched Uranium (HEU) that would remain at these domestic sites. Neither consequence is acceptable.

Highly Enriched Uranium as found at some of these research reactors is extremely dangerous in that it can be used directly to fashion a nuclear explosive. The separation of the HEU from the fuel is an elementary matter, and the fuel at most of these low-power reactor is either unirradiated fuel in storage or so lightly irradiated that there is little if any deterrent to its theft. Because many of these reactors are located on university campuses, with the open atmosphere which is such a fundamental aspect of academic life, security is not, and cannot be, anywhere near sufficient to protect weapons-grade material from potential terrorist acquisition.

The proposal to have DOE retrieve the HEU it loaned these institutions and replace it with Low Enriched Uranium (LEU) of little or no proliferation danger if stolen is sensible, admirable, and necessary. The reactors can continue their research, but the nation's security will have been inestimably enhanced. With Congressional funding of the replacement LEU fuel, transportation, and related expenditures, there should be no adverse impact on these reactors whatsoever. In fact, there would be much advantage: reduced risk of terrorist attack, reduced need for expensive and obtrusive security measures, and reduced public concern.

We understand that a few research reactor operators have expressed concern about the conversion proposal, particularly that unique research which requires HEU would be lost if conversion to LEU were required, and that public opposition and legal interventions might occur if license amendments for such conversion were needed. Both concerns seem to be misplaced.

First of all, we understand that the NRC's proposed rule provides a "unique purpose" exemption so that any reactor which could not perform its unique research with LEU would not be required to convert to LEU. The vast majority of reactors could convert without noticing any difference; those very few who might be adversely affected are to be exempted. There is no issue here.

Secondly, as to the concern that there might be public opposition and legal action taken in response to conversion license amendments, it would appear this concern is turned upside down. There have been interventions-- we even assisted in providing technical assistance to one of them-- in reactors with HEU. There, responsible citizens were concerned, correctly we believe, that the security in place was grossly inadequate to protect weapons-grade material from theft or diversion. Intervenors were pushing for conversion to LEU; had that occurred, many of the issues contested would have been resolved.

It is the presence of HEU which has led to interventions. It is removal of HEU that will protect these institutions against interventions. No group has ever opposed conversion to non-explosive fuel; several have opposed refusals to convert, however. Thus, if institutions wish to ensure public opposition and legal battles, defeat of the NRC rule is the best guarantee. If they wish to avoid these troubles, conversion is the best remedy.

We should also point out that the choice is really conversion or vastly increased security. The latter would be far more expensive, would not be paid for by Congress as will be replacement of the DOE fuels, and would substantially alter the academic environment of the affected sites. Failure to convert thus is likely to lead to closure of a number of reactors whose institutions cannot afford the very expensive task of seriously upgrading security to adequately protect weapons-grade materials, or whose Engineering Deans do not want the trouble involved with creating a high-security area with all the attendant problems in the midst of an open campus.

We have no intention of assisting any group in opposing conversion to LEU. We would, however, give serious consideration to a request for technical assistance in an NRC proceeding were the conversion rule overturned and HEU remained at research reactors. If reactor operators wish to avoid the problems UCLA was faced with, conversion would help; refusal to convert would increase, not decrease, the likelihood of public outcry and legal challenge. It is the presence of weapons-grade material that is causing so much of the public concern about these reactors in the first place.

It is instructive to remember that UCLA removed its application for license renewal one week before security hearings were to open in that proceeding, assessing the adequacy of security at the site in light of the very sensitive material possessed. UCLA could not meet its burden in demonstrating adequate security, and it has withdrawn its application. Had it converted to LEU, all of its difficult security problems would have vanished.

In conclusion, conversion is in the interests of reactor operators. Without conversion, they face continued and growing public opposition, vastly increased security requirements, and the prospect that a number of such facilities will shut down because they can't afford the additional security or because of the public concern generated by the presence of weapons-grade materials in underdefended locations. Without conversion domestically, our initiative to convert foreign reactors and reduce international commerce in HEU is doomed to failure. And perhaps most importantly, without conversion, we face the unacceptable risk that someday some group will steal weapons materials from these reactors, fabricate an atomic weapon, and threaten to, or actually proceed to explode such a destructive device, with the extraordinary results to international order that would flow therefrom, not to speak of the immense human suffering caused. The NRC proposal to replace the HEU at these reactors with non-weapons-grade materials is a cheap, prudent, and very sensible proposal, one which deserves widespread support.

October 11, 1984

Statement of Richard D. Rogge

Before the
Subcommittee on Energy Development and Applications
and the
Subcommittee on Energy Research and Production
Committee on Science and Technology
U.S. House of Representatives

Regarding
The Use of Weapons-Grade Uranium Fuel
in Domestic Research Reactors

My name is Richard D. Rogge. I am currently a security consultant. For thirty years previous, until my retirement in 1977, I was with the Federal Bureau of Investigation, during the last years as Special-Agent-in-Charge of a number of FBI field offices. In that capacity I had responsibility for assessment of and protection against potential terrorist activities in this country as well as numerous physical security duties involving the security of FBI field offices. A statement of professional qualifications is attached.

In the last two years I have been involved in some security consulting with regard to assessing the adequacy of security at a research reactor in Los Angeles which utilized what I understand to be highly enriched (i.e., weapons-grade) uranium. I reviewed the security situation at this reactor facility, which is located on an open university campus (UCLA).

I concluded that a terrorist intent on stealing the uranium from this facility would have a field day, given the woefully inadequate security posture I found. Little security attention had been paid at the facility despite the presence of weapons-grade materials on site. It was in fact one of the most undefended targets I have seen in my several decades in the security field. The perimeter was essentially indefensible, doors and locks were of ordinary construction, hinges were on the outside, there were no guards in evidence, and students and others were wandering freely and without challenge nearby.

Correction of the security problems at the facility would have required major changes, which would have been expensive and difficult, given the university setting. In fact, in part because of my recommendation, California Assemblyman Gray Davis called for and received substantial upgrading of security at the site for the few weeks of the Olympic Games, portions of which were held a few hundred feet away. This was expensive and only occurred after substantial pressure was applied. One wonders what the security situation is at other research reactors in this country which do not have the presence of the Olympics to resolve even temporarily some of the security deficiencies.

It is my impression that if the security at other research reactors around the country utilizing weapons-grade uranium is as grossly inadequate as was the apparent case at UCLA, then a serious security problem exists. There is always the possibility of a nuclear threat in this country, and we should either protect these facilities adequately, or take steps to minimize the threat.

It is for this reason that I support the proposed rule by the Nuclear Regulatory Commission to require research reactors with weapons-grade uranium to convert to low enriched, non-weapons-grade fuels which, if stolen, could not be used to make an atomic bomb. The security risks associated with a successful theft of such bomb material-- which would be relatively easy if the security at other facilities is anything like what I observed at UCLA-- appear very large.

The only other choice would be dramatically increased security at facilities that continue to possess highly enriched material. This would be very expensive to the institutions involved, not as effective as removing the risk by converting to low enriched fuels, and would likely conflict with the open environment of university campuses.

Recent events in Beirut remind one that we live in a world of terrorists, and that protective measures must be taken in a timely manner or tragedy can result. The consequences of terrorists acquiring nuclear weapons material must give pause to all persons concerned with this nation's security. It therefore seems most prudent to move expeditiously to remove the risk at these reactors by replacing weapons grade uranium with material which, if stolen by a terrorist group, could not be used to make an atomic bomb.

Thank you for your consideration of my remarks.

Richard D. Rogge
Dick Rogge and Associates Investigations
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(818)707-1836

RICHARD D. ROGGE
Professional Qualifications

My name is Richard D. Rogge. I am presently president of Dick Rogge and Associates Investigations, a professional security firm. For thirty years previous I was with the Federal Bureau of Investigation.

I entered on duty with the FBI in 1947. In 1952 I was appointed by the late J. Edgar Hoover as a Special Agent and, following a period of training at Quantico, Virginia, was assigned to the Philadelphia, Pennsylvania field office. From 1954 to 1958 I served in the Washington, D.C. field office, in 1958 being transferred to FBI Headquarters in a supervisory capacity.

In 1965 Mr. Hoover designated me Assistant Special Agent in Charge of the Richmond, Virginia field office. Subsequent promotions took me, in the same capacity, to two of the largest FBI offices, namely Philadelphia, Pennsylvania, in 1966, and Los Angeles, California, in 1967. In 1969 I was promoted to Inspector and reassigned to FBI Headquarters in Washington, D.C., where I acted as a personal representative of Director Hoover while inspecting FBI field offices. In late 1969 I became Special Agent in Charge of the Honolulu office, with subsequent promotions to Richmond,Virginia (1972), and to Buffalo, New York (1974), where I served as Special Agent in Charge until my retirement from the Bureau in 1977.

I am a member of the American Society for Industrial Security; the Association of Former Intelligence Officers; California Association of Licensed Investigators; National Association of Chiefs of Police; and the Society of Former Special Agents of the FBI, Inc.

AMERICAN COUNCIL ON EDUCATION
Division of Governmental Relations

October 17, 1984

The Honorable Marilyn Lloyd
Chairman
Subcommittee on Energy Research
and Production
Committee on Science and Technology
U.S. House of Representatives
B-374 Rayburn House Office Building
Washington, DC 20510

Re: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49 Fed. Reg. 27769)

Dear Madam Chairman:

On behalf of the American Council on Education, an association representing over 1,700 colleges, universities, and other organizations in higher education, and the associations listed below, we request that this letter be included in the hearing record pertaining to the proposed rule published on July 6, 1984, by the Nuclear Regulatory Commission to limit the use of highly enriched uranium fuel in domestic research and test reactors.

The NRC's proposed rule would affect both new and existing non-power reactors. New non-power reactors would be barred from using highly enriched uranium (HEU) fuel, fuel using uranium with an enrichment of 20% or greater, unless it could be shown that the reactors would have a "unique purpose," one which could not reasonably be accomplished without using HEU fuel. For non-power reactors currently authorized to use HEU fuel, the licensee would be prohibited from acquiring additional HEU fuel if low enriched uranium (LEU) fuel, fuel using uranium of less than 20% enrichment, acceptable to the NRC were available. The licensee would also be required to replace all its HEU fuel with LEU fuel on a schedule to be proposed by the licensee but determined by the NRC. Licensees could request NRC's permission to continue using HEU fuel upon a showing that the use of HEU fuel served a "unique purpose."

The NRC bases the need for the proposed rule on concerns over the risks that HEU material might be diverted. The higher education community strongly supports efforts by the Commission to reduce the risk of nuclear proliferation through the theft or diversion of HEU. However, we question whether the proposed rule would help to achieve this aim. We also question whether the proposed rule is not premature, in view of the federal government's ongoing program to explore the feasibility of converting existing reactors from HEU to LEU fuel. Finally, we suggest that the proposed rule would have serious financial and educational consequences for many colleges and universities, which in turn will adversely affect the nation's scientific and technical community.

No one can seriously challenge the need to take all reasonable steps to achieve the nuclear non-proliferation goals which underlie the proposed rule. However, the dramatic changes in the domestic use of HEU fuel proposed by the NRC appear to be aimed at encouraging similar actions by foreign reactor operations, rather than reducing an unacceptable risk from domestic non-power reactors. The NRC, in fact, points out in the Supplementary Information accompanying the proposed rule that domestic research and test reactors using HEU fuel "are operated without undue risk to the public health and safety." The Advisory Committee on Reactor Safeguards pointed out in its June 18, 1984, letter that the proposed rule is based on "an unidentified threat." If, as the NRC believes, the current use of HEU fuel in non-power reactors does not involve undue risks, why is any change needed? It is by no means obvious why a domestic "stick" should be used as a foreign "carrot." Nor has the Commission explained why, if HEU fuel in domestic non-power reactors somehow poses a risk, appropriate security measures would not be a suitable alternate protective strategy.

The higher education community also questions the timing of the proposed rule. Since the technical efforts to establish the workability of the rule are still in progress, consideration of the proposal at this time seems premature. The NRC points out in the Supplementary Information accompanying the proposed rule that the ability to convert non-power reactors to LEU is based on the Department of Energy's Reduced Enrichment for Research and Test Reactors (RERTR) program. However, that program has yet to be completed. In fact, the NRC states that it was encouraged to undertake this rulemaking proceeding by the "anticipated continued success over the next five years" of the RERTR program. While the NRC points out that information already developed indicates that "conversion of several non-power reactors from HEU fuel to LEU fuel is technically feasibile," the feasibility of coverting most of the remaining reactors can only be determined "if the goals of the RERTR program are successfully achieved over the next five years." Until the NRC has some better assurance that conversion is in fact technically feasible, it seems inappropriate to require licensees to submit conversion schedules and make commitments.

The prematurity of this proposal is also shown by the absence of standards and guidance to be applied by the NRC. For example, the proposed rule refers to replacing HEU fuel with LEU fuel "acceptable to the Commission." §§ 50.64(c)(2)(i), 50.64(c)(2)(ii), 50.64(c)(3), and 50.64(d)(2). Nowhere does the proposed rule explain how the NRC will determine acceptability. Similarly, the proposal gives the Director of the Office of Nuclear Reactor Regulation no guidance to be used in determining the "final schedule" for conversion to LEU fuel. § 50.64(d)(2). The NRC also indicates that an evaluation of reactor performance and safety aspects of conversion is underway, as is the possible development of generic envelopes of safety limits. Until the NRC completes its work on these important issues, and makes the resulting reports and guidance available for comment, issuance of any final rule is premature.

Regarding the financial and educational consequences, the higher education community believes that implementation of the proposed rule may well result in the shutdown of at least some domestic research and test reactors using HEU fuel. Many institutions may not have the funding necessary to carry out the conversions. While some federal funding was made available in the Fiscal Year 1985 Department of Energy appropriations bill (P. L. 98-360), there is no assurance that future funding will be forthcoming. Furthermore, conversion to LEU fuel may involve significant licensing considerations, including the possibility of extended adjudicatory hearings. Licensing costs, whether direct financial expenditures, potential delays, or both, could cause some institutions simply to close down their reactors. These non-power reactors are clearly in the national interest, both in terms of scientific and technological research and innovation and of training personnel for the nuclear industry, personnel for which there is currently an acute shortage. Forcing the closure of domestic research and test reactors would thus be highly undesirable.

With these considerations in mind, the higher education community recommends that the proposed rule not be made final in its present form. While NRC licensees may properly be asked to bear the costs of modifying their facilities to meet safety concerns -- even including the costs of shutting down those facilities -- the lack of safety concerns with respect to domestic non-power reactors strongly argues against imposing these costs on licensees of such reactors using HEU fuel.

The college and university community greatly appreciates this opportunity to express its views on this proposal. We would be happy to meet with you or your staff to discuss our concerns further.

This letter is sent on behalf of:

American Council on Education
Association of American Universities
National Association of State Universities and Land-Grant Colleges

Very truly yours,

Sheldon Elliot Steinbach

Sheldon Elliot Steinbach
General Counsel

SES:gfr

UNIVERSITY OF SOUTHERN CALIFORNIA
UNIVERSITY PARK
LOS ANGELES, CALIFORNIA 90089-1062

Statement of Dr. James C. Warf

Submitted to the Subcommittees on
Energy Research and Production
and on
Energy Development and Applications
of the
House Committee on Science and Technology
October 12, 1984

I am Professor of Chemistry, Emeritus, at the University of Southern California (USC), where I have been a member of the faculty for the last thirty-six years. Prior to that time, I spent five years with the Manhattan Project, mostly at Ames, Iowa, and to a lesser extent at the University of Chicago and at Oak Ridge, Tennessee. I specialized in the chemistry of nuclear materials and was Group Leader of the Analytical Section and, part of the time, the Inorganic Section. A more detailed statement of my professional background is attached.

I strongly support efforts to replace Highly Enriched Uranium (HEU) with Low Enriched Uranium (LEU) at research and test reactors, both in this country and abroad. HEU is weapons-usable material, and thus poses a significant risk if stolen or diverted. Removing HEU from these reactor sites and replacing it with LEU is a very prudent step, which I vigorously endorse.

If the fuel found at these reactor facilities were stolen or diverted, the weapons-grade uranium contained therein would be readily removable. This is true whether the fuel is in the form of uranium-aluminum plates or uranium-erbium-zirconium-hydride rods.

Uranium and aluminum can be separated chemically from their alloy by any number of techniques. One method is to dissolve the eutectic in hydrochloric acid, and oxidize the uranium to uranyl ion using nitric acid. Addition of excess sodium hydroxide precipitates the uranium as sodium diuranate, but converts the aluminum to the soluble aluminate ion. Separation is effected by centrifuging. Alternatively, the uranyl nitrate can be extracted by ether or butyl phosphate, leaving the aluminum in the aqueous phase. These are not difficult procedures, particularly for someone intent on acquiring an atomic explosive; one might say, in fact, that they are not beyond the ability of most students in introductory chemistry classes at the college level.

Highly enriched uranium contained in uranium-erbium-zirconium-hydride fuels is likewise readily separable by modified procedures. These are not particularly difficult tasks chemically.

If the fuel stolen were fresh (i.e., unirradiated) fuel, practically no precautions would need to be taken by the thieves to deal with radioactivity. If the fuels are only lightly radioactive, due to low power of operation or low frequency of use of many of these small research reactors, there would likewise be only a small barrier to removal and separation of weapons-usable material from such fuels if successfully stolen. For those few, high power research reactors with somewhat higher radiation levels for their fuel in-core, the highly enriched uranium could still be removed and chemically separated if the thieves took appropriate precautions. Precautions such as constantly maintaining high surface-to-volume ratios to avoid self-sustaining nuclear reaction would have to be observed in all cases.

Anyone who worked, as I did, on the Manhattan Project, and knows the extraordinary destructive power associated with highly enriched uranium when detonated, has great respect for such material. It should not be found where not needed; if low enriched fuels are available, HEU fuels should be replaced with the far safer LEU fuels.

Converting to low enriched fuels-- i.e., ones which, if stolen, cannot be made directly into a clandestine explosive-- is a very sensible policy, one which should be energetically followed.

JAMES C. WARF

Professional Vita

1939	B. S. degree in chemistry, University of Tulsa
1940	Phillips Petroleum Co.
1941-42	Instructor in Chemistry, University of Tulsa
1942-47	Group Leader, Manhattan Project (development of nuclear energy), Iowa State University (Ames), University of Chicago, Oak Ridge
1946	Ph. D. degree in inorganic chemistry, Iowa State University
1947-48	Guggenheim Fellow, University of Berne, Switzerland
1948 to the present	Assistant Professor, Associate Professor, Full Professor of Chemistry, University of Southern California, Los Angeles

Chemical education in Southeast Asia

1957-59	Visiting Professor, University of Indonesia, Jakarta
1962-64	Visiting Professor, Airlangga University, Surabaya, Indonesia
1974-75	Visiting Professor, National University of Malaysia, Kuala Lumpur
1976	Visiting Professor, National University of Malaysia, Sabah (formerly British North Borneo)
1978	Visiting Professor, Hasanuddin University, Ujung Pandang, Celebes, Indonesia
1979	Visiting Professor, Andalas University, Padang, Sumatra, Indonesia
1982-83	Visiting Professor, National University of Malaysia, Kota Kinabalu, Sabah, Malaysia

1969-70	Sabbatical leave, Visiting Professor, Technical University of Vienna, Austria

1965-74	Summer consultant, Jet Propulsion Laboratory, Pasadena, California

1945	Founding member, Federation of American Scientists

Research Fields: Rare earth and actinide hydrides and deuterides, carbides, copper hydride, crystallography, thermodynamics, kinetics, liquid ammonia chemistry of rare earth elements, electrochemistry in nonaqueous solvents, carbon-14 studies, analytical chemistry.

Publications: 65 chemistry papers in journals, 10 books (6 in Indonesian or Malaysian languages)

Travel and seminar presentation at universities in most of western Europe, Japan, Hong Kong, Singapore, Indonesia, Malaysia, Thailand, Vietnam, Cambodia, India, Soviet Union, Poland, East Germany, Austria, Czechoslovakia, Hungary, Yugoslavia, Iran, Turkey, Australia, New Zealand, Fiji Islands, Tahiti, China

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

October 29, 1984

Hon. Don Fuqua, Chairman
Subcommittee on Energy Development & Applications
House Committee on Science & Technology
Suite 2321 Rayburn House Office Bldg
Washington, D.C. 20515

Dear Representative Fuqua,

Enclosed is a letter we sent to Dr. Enzo Ricci, in response to his letter to you and Rep. Lloyd of September 19, which dealt with the September 25 Subcommittee hearings on conversion of domestic research reactor fuels.

Dr. Ricci's letter to you contained some serious errors of fact, as explained in our letter.

We believe that this illustrates the hazards of inviting and hearing the partisans of only one side of a controversy. We are unable to know what other factual errors (as distinct from differences of opinion or interpretation) may lie in the record of the September 25 hearing.

We therefore hope that thorough consideration will be given to the testimony submitted for the record by ourselves and others after the hearing concluded. If at all possible, we would like to be informed of any action the Subcommittee may take on this matter. Thank you.

Sincerely,

Steven Aftergood

Steven Aftergood
Executive Director

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COMMITTEE ON SCIENCE
AND TECHNOLOGY

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

October 29, 1984

Dr. Enzo Ricci
996 West Outer Drive
Oak Ridge, TN 37830

Dear Dr. Ricci,

We recently received a copy of your September 19, 1984 letter to Representatives Fuqua and Lloyd regarding the NRC proposed rule requiring conversion of domestic research reactors from weapons-grade fuel, and we were astounded at your comments. Several of your remarks appear to us to be in error (e.g., the amount of such material required to make an explosive device, the reduction in risk associated with conversion, etc.) But one of your statements is pure fantasy.

As part of your argument against the NRC proposal, you state that the Committee to Bridge the Gap

> has pledged to challenge all university and research reactors due for NRC relicensing. (page 3 of your letter)

This is preposterous. We have never made such a pledge. Even were such a campaign of mass interventions possible, which for legal and other reasons it probably is not, we have neither the desire nor the intention to undertake such a dubious project, and have never suggested otherwise. Indeed, over a dozen research reactors have been relicensed in the past year alone, without challenge from us or anyone else. It is irresponsible of you to have publicly stated as fact this outrageous fabrication.

Your larger concern that passage of the NRC rule, along with the license amendments which will likely be required, will lead to interventions and public hearings is easier to understand, but it is likewise mistaken. In fact, as explained below, the opposite is closer to the truth: It is continued use of highly enriched uranium (HEU) which will lead to public controversy.

In the first place, it should be recognized that there have been literally hundreds of license amendments to nonpower reactors in the last several years. They are routinely published in the Federal Register. Many amendments are for a change in reactor operation in the direction of increased risk, e.g. a tenfold increase in power. Yet there has never been a single intervention with regard to these amendments.

It is therefore practically unthinkable that license amendments to allow conversion to low enriched uranium (LEU) fuel will face interventions and public hearings, particularly since conversion will yield a more secure and in some cases a safer reactor, aside from its other benefits. Witness the fact that in the abundance of public comments on the NRC proposal, there is not a single expression of opposition to conversion from the general public. The public supports the measure, and is determined to see it implemented. And, for your information, the potential for intervention on any proposed amendment is limited by law to the scope of the amendment. In other words, one could not raise issues unrelated to conversion when challenging conversion amendments. Therefore, no full scale intervention as in the UCLA case is even conceivable with regard to such amendments. And again, there is no individual or organization that we know of who would possibly try to challenge conversion in and of itself.

Let me reiterate our own position. We will not intervene, nor would we assist others to intervene, to block conversion to LEU.

On the other hand, in light of the strong public support for conversion, one should consider the implications for nonpower reactors of rejection or weakening of the NRC proposal, e.g. to exclude reactors with lifetime HEU cores. In such an event, I believe, licensees that continue to use HEU will be overwhelmed by public controversy. Those facilities due for relicensing will likely face interventions. Others will face other sorts of pressures from their communities and institutions, as well as the possibility of legal action. Our review of the NRC dockets of nonpower reactors has revealed an abysmal state of security preparedness at many facilities, totally inadequate to protect special nuclear materials against a serious threat. And so we would in some instances find reason to support such public efforts.

In light of this situation, it appears that it is retention of HEU rather than conversion that will lead to greater stress on nonpower reactors, including the possibility of total shutdown. Aside from public concern, at least two factors lead independently to this conclusion. First, facilities which use or convert to LEU will be easier to relicense. This certainly would have been the case in the UCLA reactor proceeding, from which UCLA withdrew one week before the long-awaited hearings on security at the site unable, we think, to meet its burden of proof that it could adequately protect its HEU fuel.

Secondly, the NRC will ultimately require a substantial upgrading of security for those facilities continuing to use HEU, well beyond even the new security requirements the Staff is currently discussing. And unlike conversion, the cost of these measures will have to be borne by licensees, not by the government.

For these and other reasons, we believe that the interests of nonpower reactor licensees coincide with the NRC position represented by the proposed rule, and with the public will to reduce the use of HEU as far as possible.

In the future, if you require further clarification of our position, we invite you to contact us directly.

Sincerely,

Steven Aftergood

Steven Aftergood
Executive Director

cc: Rep. Don Fuqua
Rep. Marilyn Lloyd
A. Francis DiMeglio
Joseph M. Hendrie
Secretary of the NRC

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone (312) 352-6611 **Telex 254635**

November 1, 1984

Honorable Don Fuqua, Chairman
House Committee on Science and Technology
2269 Rayburn House Office Building
Washington, DC 20515

Honorable Marilyn Lloyd, Chairman
House Subcommittee of Energy Research and Production
2334 Rayburn House Office Building
Washington, DC 20515

Honorables Don Fuqua and Marilyn Lloyd:

American Nuclear Society Comments on Proposed HEU/LEU Conversion Rule

Reference: "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors," National Regulatory Commission Proposed Rule, Federal Register, Vol. 49, No. 131 (July 6, 1984), pp. 27769-72.

I am enclosing comments sent by the President of the American Nuclear Society (ANS), Dr. Joseph M. Hendrie, to the National Regulatory Commission (NRC) on behalf of the ANS. The enclosure states the opposition of the ANS to the enactment of the proposed NRC rule, and details a number of solid reasons for this opposition.

As you may recall, appropriations for this proposed rule were discussed at a joint meeting of the House Subcommittees of Energy Research and Production and of Energy Development and Applications on September 25, 1984.

Sincerely,

Enzo Ricci

Enzo Ricci
National Board of Directors

cc: Louis Ventre, Jr.
J. M. Hendrie

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone (312) 352-6611 Telex 254635

October 22, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555
Attn: Docketing and Service Branch

Dear Mr. Secretary:

Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

References:

1. E. L. Zebroski, EPRI, "Relative Diversion Exposures of HEU: Relation to University Research Reactors," presented to the ANS 1984 Annual Meeting, New Orleans, LA, June 3-8, 1984.
2. A. F. DiMeglio, TRTR, "Conversion of Domestic Research and Test Reactors to LEU Fuel," presentation before U.S. House Subcommittees on Energy Development and Applications and Energy Research and Production, September 25, 1984.
3. "ACRS Report on Proposed Rule for Limiting the use of HEU in Domestic Research and Test Reactors," Letter: J. C. Ebersole to N. J. Palladino, June 18, 1984.

The American Nuclear Society (ANS) would like to comment on the subject proposed NRC rule, published in the Federal Register (No. 10 CFR, Part 50), Vol. 49, No. 131, July 6, 1984, pp. 27769-72.

The ANS has been following the NRC activities concerning the Highly-Enriched to Low-Enriched (HEU/LEU) Conversion issue. Our past president, Milton Levenson, expressed a number of serious concerns in a letter to the NRC chairman on March 19, 1984. The chairman of the ANS Education Division, John W. Lucey, also addressed the NRC chairman on May 23, opposing the issuance of the proposed rule. On June 11, I sent Dr. Palladino a copy of a paper by Edwin L. Zebroski (Reference 1), in which he concluded that the diversion risk is minimal for non-power reactors. I suggested in my letter that a more systematic and thorough analysis of these risks would be prudent before issuance of the proposed rule.

In this correspondence the ANS has examined in detail many of the potential problems and risks that the HEU/LEU Conversion rule would pose. The following comments and recommendations summarize the consensus of the ANS organizational bodies, divisions, and individual members knowledgeable of, and/or concerned with, the HEU/LEU Conversion issue.

Comments:

1. Education is one of our highest national priorities because of its relevance to U.S. progress and security. Research and test reactors are of major importance in assuring an adequate supply of professionally trained workers for the essential fields of nuclear engineering, nuclear physics, nuclear chemistry, and activation analysis. . The proposed rule would weaken nuclear engineering academic programs already diminished due to inadequate research support.

2. Licensed research and test reactors are an important source of short-lived isotopes for medical research and diagnosis. Reactor shutdowns would likely result from application of the proposed rule, due to the protracted, expensive and uncertain legal procedures that relicensing may require. (See No. 6 below). These shutdowns would probably lead to the cancellation of many teaching, scientific, and medical programs. Shutdowns would not only affect programs at the university or center where the reactor is located, but those of many other universities which have access to, and also use these reactors.

3. While feasibility of HEU/LEU conversion was demonstrated at Argonne for some reactors, the required technology for other reactors is still undemonstrated. Further, LEU fuels for intermediate power reactors, developed in the Argonne program, have not been tested under highly stringent or long-term conditions as the existing HEU fuels have. Also, reload to constant power but reduced flux, a likely outcome of conversion, can significantly affect important programs in radioisotope production, nuclear physics, and activation analysis.

4. In Reference 1, Zebroski points out that (a) the U.S. research and test reactors pose a very low diversion risk; (b) future conversion of overseas reactors (if encouraged by conversion in the U.S.) would not materially affect the risks associated with nearly 20 tons of HEU already exported; and (c) the relative risks, benefits, and social impacts of fuel changes in domestic non-power reactors have not been studied thoroughly.

5. A. F. DiMeglio presented the views of the National Organization of Test, Research and Training Reactors (TRTR) to a joint subcommittee hearing of the U.S. House of Representatives (Reference 2). He emphasized that HEU/LEU conversion of U.S. non-power reactors would not set an adequate example to overseas operators, and quoted a letter from P. von der Hardt, chairman of the European TRTR:

   > "The impact on overseas reactors would therefore be limited to installations below 5 MW which, as in the United States, consume only a minor fraction of the total HEU in circulation."

Hardt concluded that the rule's expressed hope that the U.S. conversion may encourage similar action abroad "appears to be premature."

6. In the proposed rule the NRC requests comments on the concept of "generic envelopes of safety limits," and also on the extent that the economics of conversion should influence NRC actions. We believe that, due to both the significant core changes the conversion would require for many reactors, and the virulence of intervenor groups, it is likely that relicensing after conversion may lead to lengthly and expensive public hearings with unpredictable results. It is sobering to recall the recent decision of UCLA to withdraw its application for license renewal and to decommission its facility after four years of relicensing hearings at an estimated cost to UCLA of $500,000. There are few facilities which could afford such legal expenses and many reactor shutdowns will likely occur. We feel that it would be unrealistic to believe that this outcome could be prevented by involving generic envelopes.

7. The NRC also requests comments on the possiblity that a license amendment may not be required. For the reasons given in Item 6 we believe that licence amendments will be required. In this context, in its recent report to the NRC (Reference 3), the Advisory Committee on Reactor Safeguards foresees the possibility of hearings with public intervention, and recommends that the NRC evaluate whether these hearings "are serving their intended function effectively."

Recommendations

Because of the above considerations, the ANS consensus opinion is that the proposed HEU/LEU conversions of research and test reactors should not take place and, thus, the proposed rule should not be enacted.

We understand that the NRC is charged with protecting the health, safety and well-being of the general public in all aspects of the use of nuclear energy. In the proposed rule, however, the Commission may be interpreting its function in a narrow sense, to hastily achieve a goal of unclear usefulness. By pursuing this goal, the NRC may be responsible for the diminution of the teaching and research capabilities of U.S. universities in the life, physical, natural and engineering sciences and may have misinterpreted its mandate to the nation.

If the NRC still decided to issue the rule, it is essential that before enactment, a systematic and thorough analysis be made of the relative risks of diversion from non-power reactors, and of the relative benefits and social impacts of the conversion. These social impacts include, not only the direct cost of conversion, but also relicensing burdens to facilities, including litigation and loss of overhead funds for the staff involved in relicensing procedures.

Sincerely,

JM Hendrie

Joseph M. Hendrie, President
American Nuclear Society

cc: ANS Board of Directors
N. J. Palladino
O. J. DuTemple

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

December 4, 1984

Rep. Don Fuqua, Chairman
House Committee on Science
and Technology
Rayburn House Office Building
Washington, D.C. 20515

RE: Proposed NRC Rule on Conversion of Nonpower Reactors from Highly Enriched Uranium (HEU) to Low Enriched Uranium (LEU) Fuel

Dear Rep. Fuqua,

I am enclosing for your information a recent clipping from the UCLA Daily Bruin, regarding the epidemic of campus burglaries using unauthorized keys to restricted areas.

Our review of NRC inspection reports from the last several years indicates that this problem of poor key control is not limited to UCLA. NRC inspectors at research reactors around the country have frequently discovered instances of missing keys, failure to timely re-key reactor facilities, failure to retrieve keys to reactor areas from former employees and students, and so on.

This phenomenon suggests that the probability of a potential thief gaining access to a supposedly secure area on a university campus is very high. Of all nuclear facilities, it is by far the low power university reactors whose security posture is weakest. It therefore seems appropriate that these should be the first to convert to LEU fuels, as per the NRC proposal.

Sincerely yours,

Steven Aftergood

Steven Aftergood
Executive Director

cc: Harlan Watson

monday, november 19, 1984 ucla daily bruin

Burglaries linked to loose passkeys

By Chris Howell
Staff Writer

About 90 percent of UCLA's burglaries involve use of stolen, unauthorized or illegally duplicated university keys, according to a University of California police investigator.

The majority of thieves at UCLA use passkeys to access rooms instead of breaking locks or windows; that is why most burglarized rooms show no signs of forced entry, UCPD detective B. Franklin said.

On Oct. 15, a UCLA employee reported that someone had stolen 50 university keys and a list of the rooms the keys accessed in Campbell Hall, and on Nov. 9 another 18 keys were reported missing from the same building. A Campbell Hall employee requested an extra patrol in the building on Nov. 8 because someone had opened desks, cabinets and inner offices, and on Nov. 12 video equipment was reported stolen from a locked Campbell Hall desk.

But there is "no way to say for sure" that the Campbell burglaries are related to the key thefts, said Franklin, because there were thefts from the area that showed no signs of forced entry before these incidents. Franklin added that the recent Campbell Hall key thefts are only part of the widespread burgalary problem.

"Probably 90 percent of our burglaries here (at UCLA) are done by using keys," Franklin said, adding that it is difficult to keep track of the thousands of keys issued by a large institution like UCLA.

"People are trying, but there are so many keys and so many people who have a need for keys that it's hard to control," Franklin said. He cited one instance where a burglar had probably used a passkey to enter an office where only three employees had access.

There may be a demand for UCLA keys within the Los Angeles criminal community, according to Franklin. "We've heard from suspects that you could sell a ring of university master keys for $100."

All university keys have an imprint saying "do not duplicate," but locksmiths and

Continued on Page 8

Passkey burglaries

Continued from Page 1

criminals still duplicate the keys without authorization, Franklin said. UCLA employees, ex-employees, and people not affiliated with the university have all been implicated in past passkey burglaries, he added.

APPENDIX 3

ADDITIONAL MATERIALS FOR THE RECORD

POLICY STATEMENTS

Use of High-Enriched Uranium (HEU) in Research Reactors; Policy Statement

AGENCY: U.S. Nuclear Regulatory Commission.

ACTION: Statement of policy.

SUMMARY: The Nuclear Regulatory Commission (NRC) has licensing responsibility for domestic use and for export abroad of Special Nuclear Material, including High-Enriched Uranium (HEU), and is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors. The NRC is pleased to note that the current U.S. Administration continues to support the Reduced Enrichment for Research and Test Reactors program and that to date the U.S. Congress has approved adequate funding for this program. In this connection, the NRC has prepared the following policy statement.

FOR FURTHER INFORMATION CONTACT: James V. Zimmerman, Assistant Director, Office of International Programs, U.S. Nuclear Regulatory Commission, Washington, DC 20555, (301) 492-7806.

SUPPLEMENTARY INFORMATION:

In the 1950's the U.S. entered into several short-term agreements for cooperation (5–10 years) allowing for the export of research reactors and fuel under the "Atoms for Peace" program. In subsequent years the U.S. has been a major supplier of high-enriched uranium (HEU) for use abroad, primarily in research and test reactors. Such reactors produce radioisotopes for use in such areas as medicine, agriculture, desalination, research in biological effects of radiation, etc. Materials test reactors are also used to train future operators of commercial power reactors and to test new materials and fuels.

In the mid 1970's, particularly following India's detonation of a nuclear explosive device in 1974, nuclear proliferation concerns began to increase. Expanded efforts were undertaken to prevent nuclear power programs from being exploited to produce nuclear weapons. Particular concerns were expressed with respect to the proliferation risks associated with inventories of HEU for research and test reactors abroad. The widespread use of HEU fuel, which involved a large number of domestic and international fuel shipments, increases the risks of proliferation through theft or diversion of this material. In contrast to HEU, the use of fuel with lower enrichments reduces proliferation risks.

In an effort to allay concerns of proliferation risks, efforts were made to reduce HEU inventories, on the assumption that any reduction in the potential for access to these inventories would constitute a reduction in the proliferation risk. These concerns eventually led to the establishment of the reduced enrichment for research and test reactors (RERTR) program. This program was established to develop and demonstrate the technology that will facilitate the use of reduced-enrichment uranium fuels in research and test reactors. If successful, this could lead to a significant reduction of HEU inventories abroad, and thereby increase the proliferation resistance of related fuel cycles.

The objective of the RERTR program is to develop research and test reactor fuels which will allow substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics or fuel cycle costs. On an interim basis, some reactors may utilize intermediate enrichment fuels (45%), while the LEU fuel development program is in progress. It should be noted, however, that no U.S. effort will be made to develop fuels with enrichments significantly below 20%, because of the increasing magnitude of plutonium production in fuels with very low or no enrichment.

To date, DOE has initiated a development and test program managed by the Argonne National Laboratory (ANL) to prove the feasibility of the new lower enrichment fuels. Many foreign countries are cooperating with the U.S. in this effort, and, within the past year, NRC has issued several export licenses for reduced-enrichment uranium to be fabricated into test elements for foreign and domestic research reactors.

Assuming RERTR program success, most of the performance testing of LEU aluminide and oxide fuels with high uranium densities for use in plate-type reactors will be completed by the end of 1984. The irradiation of pin-type zirconium hydride fuel with high uranium density for use in Triga-type, and possibly plate-type, reactors will be completed in 1983. Assuming licensing approvals, these fuels could then enter into full scale use in appropriate reactors. Silicide fuels with very high uranium densities are also being developed and tested by the RERTR program. These fuels may be needed for conversion of high power reactors.

As part of the overall RERTR program, Argonne conducts for DOE a technical and economic evaluation of each significant HEU export license application including the potential of the reactor for conversion to reduced-enrichment fuel within the planned availabilities of appropriate reduced-enrichment fuels. Nearly all potential conversion candidates have been evaluated. Technical conversion schedules are being planned by reactor operators based on demonstration and licensability of the fuel. Based on the technical and economic evaluation by ANL, a coordinated Executive Branch recommendation on the license application is developed by the Department of State and is submitted to the NRC.

The objectives of the RERTR program have been fully supported by NRC since its inception. The Commission has also utilized Argonne's analyses in support of its reviews of proposed interim exports of HEU, particularly with respect to determining the dates when conversion to lower-enriched fuels can be anticipated. The Commission is pleased to note that the current Administration continues to support the RERTR program and that Congress has approved adequate funding for the program.

The Commission also notes that several types of LEU fuel are currently being tested in DOE's RERTR program. As soon as all the necessary tests are completed, the Commission is prepared to act expeditiously to review the use of the new fuel in domestic research and test reactors licensed by NRC.

With respect to future export license applications for HEU, bearing in mind the Commission's responsibility to make an overall finding that each export would not be inimical to the common defense and security of the U.S., the Commission intends to continue its current practice of careful scrutiny to verify that additional interim HEU exports are justified. The Commission

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[1] The policy statement states that "[s]anctions will be imposed on licensees who fail to meet their obligations *with respect to Commission requirements.*" (emphasis added) Thus, the statement implies that its coverage extends to the provision of information in addition to that which is legally required and enforceable.

September 1, 1982

plans to continue to monitor the progress of the RERTR program so that it can understand what would be appropriate conversion schedules, and to encourage that actions be taken to eliminate U.S.-supplied inventories of HEU to the maximum degree possible.

The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps [1] to encourage similar action by U.S. research reactor operators.

Dated at Washington, D.C. this 17th day of August, 1982.

For the Commission.

Samuel J. Chilk,

Secretary of the Commission.

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[1] Because the "steps" referred to in the above sentence have not been detailed or discussed, Commissioner Roberts does not agree to the sentence since it implies that a specific course of action will be followed by the NRC.

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47 FR 50591
Published 11/8/82

Licensing and Regulatory Policy and Procedures for Environmental Protection; Uranium Fuel Cycle Impacts

AGENCY: Nuclear Regulatory Commission.

ACTION: Statement of policy.

Earlier this year a decision of the United States Court of Appeals for the District of Columbia Circuit vacated three Commission rules which govern the treatment of uranium fuel cycle environmental impacts in individual nuclear power reactor licensing proceedings. *Natural Resources Defense Council, et al.* v. *NRC*, No. 74-1586 and consolidated cases (decided April 27, 1982).[1] By its order of September 1, 1982, the D.C. Circuit stayed its mandate pending the filing of application for review of the decision by the Supreme Court. The Solicitor General, on behalf of the Nuclear Regulatory Commission, on September 27, 1982, filed with the Supreme Court a petition for a writ of *certiorari*. Other parties to the case have also filed petitions for Supreme Court review. In this Statement of Policy the Commission provides guidance to the Commission's staff and licensing boards and the interested public regarding ongoing licensing proceedings and the status of licenses already issued, pending final action by the Supreme Court.[2]

1. Background of the Decision in NRDC v. NRC

The rules in question form part of the Commission's procedures for compliance with the National Environmental Policy Act of 1969 (NEPA). 10 CFR Part 51. The Commission has interpreted NEPA as requiring that the environmental impacts of the uranium fuel cycle be considered in environmental impact statements for individual light water nuclear power reactors.[3] The Commission determined some time ago that a generic rule would be the most effective means for considering such impacts in individual reactor licensing proceedings. The most recent version of the Commission's fuel cycle rule, the "Final" fuel cycle rule, was promulgated in 1979. 44 FR 45362 (August 2, 1979). 10 CFR 51.20, 51.23. The rule is frequently referred to as "Table S-3," after the table of impacts which the rule prescribes for use in evaluating the fuel cycle contribution to the environmental costs of licensing an individual nuclear power reactor. In issuing reactor construction permits and operating licenses the Commission has relied on this fuel cycle rule or its predecessors (the "Original" and "Interim" rules) since adoption of the Original rule in 1974. 39 FR 14188 (April 22, 1974).

Litigation involving the fuel cycle rules began with the Original S-3 rule. In a decision issued July 21, 1976 the United States Court of Appeals for the District of Columbia Circuit set aside those portions of the Original rule pertaining to waste management and spent fuel reprocessing. *Natural Resources Defense Council* v. *NRC*, 547 F.2d 633, rev'd *sub nom. Vermont Yankee Nuclear Power Corp.* v. *NRC*, 435 U.S. 519 (1978), but the court stayed its mandate pending review on a petition for *certiorari* to the United States Supreme Court. The Supreme Court reversed the Court of Appeals and remanded for further proceedings. The Court of Appeals consolidated the remanded case with challenges to the Commission's Interim and Final fuel cycle rules and issued a decision on April 27, 1982. *NRDC* v. *NRC*, No. 74-1586 and consolidated cases.

2. The Holding by the Court of Appeals

In the D.C. Circuit's decision in *NRDC* v. *NRC*, Judge Bazelon, speaking for the majority, held the Commission's Original, Interim and Final Table S-3 rules invalid "due to their failure to allow for proper consideration of the uncertainties that underlie the assumption that solidified high-level and transuranic wastes will not affect the environment once they are sealed in a permanent repository." Slip Op. at 69. The court's opinion acknowledged that in promulgating the Final rule the Commission considered and disclosed uncertainties concerning permanent disposal of spent fuel and high-level wates from power reactors. *See* the Commission's notice of final rulemaking, 44 FR 45362 (August 2, 1979). The court did not suggest that the evidentiary record for the Commission's final rulemaking omitted any substantial body of material regarding waste disposal uncertainties which might have been available at the time of the rulemaking. Nevertheless, the court held it to be a violation of NEPA that the rule binds Licensing Boards to evaluate fuel cycle impacts on the basis of waste disposal impacts in Table S-3, which does not explicitly include uncertainties.[4]

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[1] On June 30, 1982 the D.C. Circuit denied the Commission's petitions for rehearing and rehearing *en banc*.

[2] The Commission dealt with a previous invalidation of a fuel cycle rule by the D.C. Circuit in 1976 by issuance of a policy statement. *Natural Resources Defense Council* v. *NRC*, 547 F.2d 633, rev'd *sub nom. Vermont Yankee Nuclear Power Corp.* v. *NRC*, 435 U.S. 519 (1978). *See* General Statement of Policy, 41 *Fed. Reg.* 34707 (August 16, 1976), and Supplemental General Statement of Policy, 41 *Fed. Reg.* 49898 (November 11, 1976). For reasons discussed in the text below, the Commission does not believe that the major, though temporary, disruption in licensing occasioned by the policy statement of August 1976 is a necessary or appropriate response to the D.C. Circuit's latest decision.

[3] In addition to the operation of the nuclear power reactor itself, the uranium fuel cycle includes uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, spent fuel storage and disposal, possible reprocessing of irradiated fuel, transportation of radioactive materials and management of low- and high-level wastes.

[4] Concerning the choice not to include uncertainties explicitly in Table S-3, the Commission stated in promulgating the rule:

In view of the uncertainties noted regarding waste disposal, the question then arises whether these

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON D.C. 20555

OFFICE OF THE
SECRETARY

September 3, 1981

PDR cy

MEMORANDUM FOR: William J. Dircks, Executive Director for Operations

FROM: Samuel J. Chilk, Secretary

SUBJECT: SECY-81-430 - APPROVAL OF A PROPOSED LICENSE TO EXPORT HIGH ENRICHED URANIUM TO THE FEDERAL REPUBLIC OF GERMANY (LICENSE NO. XSNM01808)

This is to advise you that the Commissioners have reviewed the subject license to Transnuclear, Inc. The Commission (with three Commissioners approving) has accepted your recommendation to export to the Federal Republic of Germany 31.3 kilograms of uranium, enriched to 93.3% U-235, and 64.7 kilograms of uranium, enriched to 45.4% U-235, in the form of UF_6.

In connection with his approval, Chairman Palladino has provided the following statement:

"I am concerned about the use of highly enriched uranium in research reactors and the relationship of the Commission's export licensing responsibilities to it. I am heartened by the efforts to phase out the use of HEU in such reactors, and believe such efforts should be accelerated. I request that the Commission direct the staff to prepare a policy statement for Commission consideration on this general subject."

The other Commissioners have concurred in this request.

Commissioners Gilinsky and Bradford have approved only 64.7 kilograms of 45% material and are not satisfied with the justification for further fuel shipments. They would wait to see if special circumstances develop which would warrant shipment of additional HEU.

The Commission requests that the staff provide the policy statement requested by Chairman Palladino by September 22, 1981.

The Office of International Programs was informed of this action by telephone on September 2, 1981.

cc: Commissioners
Commission Staff Offices
Director, International Programs
Public Document Room

8110010197 810831
PDR 10CFR

January 8, 1982

SECY-82-10

POLICY ISSUE
(Notation Vote)

For: The Commission

From: William J. Dircks
Executive Director for Operations

Subject: PROPOSED NRC POLICY STATEMENT ON THE USE OF HIGH-ENRICHED URANIUM (HEU) IN RESEARCH REACTORS

Purpose: To provide the Commission a draft proposed NRC policy statement on HEU use.

Discussion: On September 1, the Commission requested the staff to prepare a policy statement on the use of high-enriched uranium (HEU) in research reactors. This request was proposed initially by Chairman Palladino in connection with his approval of XSNM01444, an export of HEU to West Germany. (See Appendix A)

Subsequently, while developing that statement, the staff learned that a preliminary decision had been made by the DOE Assistant Secretary for Nuclear Energy to terminate the Reduced Enrichment Research and Test Reactor (RERTR) program (funding at that time was proposed to be reduced to $500,000, which was earmarked for close-out costs). In view of the critical relationship between the RERTR program and the nature of the Commission's proposed HEU-use policy statement, the staff deferred action on the statement pending further developments on the RERTR budget.

We have now been informed that adequate funding for the RERTR program is expected to be provided. The latest information also indicates that the program, while still remaining under

Contact:
Wm. Upshaw, IP (49-28155)

Discussion:
(Continued)

Argonne's control, will likely be funded under ACDA's budget commencing in FY83.

[The Commission will recall that in May, it forwarded to Congress a letter expressing support of the RERTR program and its concern regarding possible budget cuts (Appendix B). In addition, in October the Commission forwarded to the Deputy Secretary of Energy a letter requesting that the decision to terminate support for the RERTR program be reviewed and reversed (Appendix C)].

The staff has prepared a draft policy statement for Commission consideration at Appendix D. To assist in the review of this draft statement, we have attached a report (Appendix E), which provides a detailed summary of the status of fuel conversion efforts with respect to essentially all foreign research reactors utilizing U.S.-origin HEU. A key conclusion of the Argonne report states that if RERTR is successful, "... no HEU might need to be exported after 1987 to fuel foreign MTR-type and TRIGA-type research reactors". Furthermore, Table 3 of the report indicates that the bulk of the exports could be completed by 1983.

Recommendation:

That the Commission approve for public dissemination the proposed policy statement at Appendix C, after final confirmation that the RERTR program will be funded adequately in FY82. Staff will keep the Commission informed on this point. Also, before disseminating the statement, the Commission may wish to inform the Executive Branch of its contents.

William J. Dircks
Executive Director for Operations

Appendices:
A - SECY Memo, S31-489 dtd. 9/1/81
B - Ltr to Congress fm Chrmn
dtd 5/12/81
C - Ltr to DOE fm Chrmn Palladino
dtd 10/29/81
D - Proposed NRC policy
statement
E - Status of Final Conversion
Efforts (C)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

May 12, 1981

The Honorable Don Fuqua, Chairman
Committee on Science and Technology
United States House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

The Department of Energy, along with the Department of State and the Arms Control and Disarmament Agency, has for some time supported and provided funding for the Reduced-Enrichment in Research and Test Reactors (RERTR) Program. The NRC also has supported and monitored this program and has a strong interest in its timely completion.

As you know, this program was undertaken to facilitate a significant reduction in US-supplied inventories of highly-enriched uranium (HEU) at dispersed sites of research and test reactors abroad. Reducing the quantities of weapons-grade enriched uranium in circulation will contribute significantly to the reduction of worldwide safeguards and proliferation concerns.

The program includes a number of joint activities designed to demonstrate the feasibility of utilizing medium-enriched (MEU 45%) and low-enriched (LEU ~ 19.85%) fuels in such reactors. Operators of research reactors in a number of foreign nations have agreed to participate in joint analytical studies and/or experimental verification activities in support of this U.S. nonproliferation initiative. Since conversion to LEU fuels would be most effective, the potential efficacy of such fuels for the majority of research reactor applications should be established promptly.

It has come to the Commission's attention that the budget allocations for this program may be reduced to levels which may preclude timely achievement of program objectives. The resulting deferral could undermine both the credibility of U.S. policy in the international nuclear community and the potential for future foreign cooperation and support of other nuclear technical initiatives which the U.S. might wish to propose. This applies particularly to those countries which have made major commitments to this program as a result of U.S. pressure.

We urge your consideration of a funding level for the RERTR Program that would permit its expeditious completion and the benefits of the program in terms of significant reductions in HEU exports from the U.S. to be realized.

Sincerely,

JM Hendrie

Joseph M. Hendrie

cc: Rep. Larry Winn, Jr.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

October 29, 1981

The Honorable W. Kenneth Davis
Deputy Secretary
U. S. Department of Energy
Washington, D. C. 20585

Dear Mr. Davis:

The Commission has just learned that a budgetary decision has been made by DOE that would, in effect, terminate the Reduced Enrichment Research and Test Reactor (RERTR) Program in FY 1982.

As described in our recent letter to Congress (enclosed), the Commission strongly supports this program. At the behest of the U. S., some 35 nations are participating in this program which seeks to advance the key U. S. non-proliferation objective of developing proliferation resistant fuels and fuel cycles. It appears that termination of the RERTR program at this time would prevent the documentation of irradiation performance of the current technology LEU-fuels applicable to conversion of research reactors having power levels below 2MW. Termination would also preclude needed development and demonstration of commercial fabrication technology for and irradiation performance of the advance technology LEU-fuels which should be able to meet the needs of nearly all the medium and high power research and test reactors in the 1980's. If the program were terminated, encouraging results of the research and development in this area, and a large part of the millions of dollars expended over the past four years by both the U. S. and our allies would have been wasted. This would not only be a technical and financial waste, but it would also serve to erode our allies' confidence in the U. S. as a reliable supplier of nuclear material.

Without continued U. S. development of LEU fuel alternatives, foreign research reactor operators would have no alternative but to continue to utilize high enrichment uranium. This could have an undesirable impact on the Commission's ability to make a finding that such exports of HEU are not inimical to the common defense and security of the U. S.

Relevant also to your consideration of this matter is, of course, the commitment made in your recent speech before the IAEA

General Conference in which you stated "[W]e also intend to continue to work with others in substituting LEU for HEU in the fueling of research reactors and to continue to work for measures to enhance the security of international transportation of weapons usable nuclear materials."

DOE's termination of the RERTR program could undermine both the credibility of U. S. policy in the international nuclear community and the potential for future foreign cooperation and support of other nuclear technical initiatives which the U. S. might wish to propose. This applies particularly to those countries which have made major commitments to this program as a result of U. S. pressure.

Commissioner Ahearne agrees that the decision to terminate support of RERTR should be reviewed and reversed. He believes DOE's termination of the RERTR program could undermine both the credibility of U. S. policy in the international nuclear community and the potential for future foreign cooperation and support of other nuclear technical initiatives which the U. S. might wish to propose. However, he does not agree with the Commission's position that this properly affects findings required by the NNPA for exports. As a general matter he would not penalize other countries because the U. S. failed to fulfill its commitments.

The Commission believes that reversal of this decision is urgently required and hopes that you give it your personal attention.

Sincerely,

Original signed by
Nunzio J. Palladino

Nunzio J. Palladino

Enclosure
May 12, 1981 ltr to Representative Don Fuqua

cc: The Honorable Richard T. Kennedy
Under Secretary of State for Management

The Honorable Eugene Rostow
Director
Arms Control and Disarmament Agency

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Originating Office: EDO/IP

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DATE	10/20/81	10/2/81	10/22/81	10/28/81	10/28/81	

Proposed NRC Policy Statement on the Use of High-Enriched Uranium (HEU) in Research Reactors

In the 1950's, the U.S. entered into several short-term agreements for cooperation (5-10 years) allowing for the export of research reactors and high-enriched uranium (HEU) fuel under the "Atoms for Peace" program. In subsequent years the U.S. has been a major supplier of HEU for use abroad, primarily in research and test reactors. Such reactors produce radioisotopes for use in such areas as medicine, agriculture, desalination, research in biological effects of radiation, etc. Materials test reactors are also used to train future operators of commercial power reactors and to test new materials and fuels.

In the mid-1970's, particularly following India's detonation of a nuclear explosive device in 1974, nuclear proliferation concerns began to increase. Expanded efforts were undertaken to prevent nuclear power programs from being exploited to produce nuclear weapons. Particular concerns were expressed with respect to the proliferation risks associated with U.S.-supplied inventories of HEU for research and test reactors abroad. The widespread use of HEU fuel, which involves a large number of domestic and international fuel shipments, increases the risks of proliferation through theft or diversion of this material. In contrast to HEU, low or medium (45%) enriched uranium cannot practically be used directly in nuclear-explosive devices, and thus, its use clearly reduces proliferation risks.

In an effort to allay concerns of proliferation risks, efforts were made to reduce HEU inventories, on the assumption that any reduction in the potential for access to these inventories would constitute a reduction in the proliferation risk. These concerns eventually led to the establishment of the reduced enrichment for research and test reactors (RERTR) program. This program was established to develop and demonstrate the technology that will facilitate the use of reduced-enriched uranium fuels in research and test reactors. This will, in turn, result in a significant reduction U.S.-supplied HEU-inventories abroad, and thereby increase the proliferation resistance of related fuel cycles.

The near-term objective of the program is to use current technology to achieve the lowest feasible fuel enrichment for readily-convertible research reactors. Fuel fabrication technology currently available permits enrichment reduction from 90-93% to 30-45% in many MTR fuel designs without a reduction in reactor performance.

The long-term goal of the RERTR program is to develop research and test reactor fuels which will allow substitution of uranium of lower enrichment (ideally less than 20% uranium-235) for HEU and will not significantly affect reactor performance characteristics.

To date, DOE, under the program direction of Argonne National Laboratory, has initiated a development and test program to prove the feasibility of the new lower enrichment fuels. Several foreign countries are cooperating with the U.S. in this effort, and, within the past year, NRC has issued several export licenses for reduced-enrichment uranium to be fabricated into test elements for foreign research reactors.

Most of the performance testing of "current technology" LEU fuel (for low power research reactor applications) is expected to be completed by 1984, after which the LEU-aluminide oxide fuels, assumining licensing approvals, would enter into full-scale use in appropriate reactors.

As part of the overall RERTR program, Argonne conducts a technical evaluation of each significant HEU export license application including the potential of the reactor for conversion to reduced-enrichment fuel within the planned availabilities of appropriate reduced-enrichment fuels. Nearly all potential conversion candidates have been evaluated, and tentative conversion schedules proposed.

The objectives of the RERTR program have been fully supported by NRC since its inception. The Commission has also utilized extensively Argonne's analyses in support of its reviews of proposed interim exports of HEU, particularly with respect to determining the dates when conversion to lower-enriched fuels can be anticipated. The Commission is pleased to note that the current Administration continues to support the RERTR program and that Congress has approved adequate funding for the program.

The Commission also notes DOE's commitment of some of its own research and test reactors to demonstration of the use of lower enrichment fuel. In order to be assured of continuing foreign cooperation in the RERTR program, it is essential that the U.S. continue to subject its own reactors to the same conversion goals adopted abroad. As soon as all the tests are completed, the Commission is prepared to act expeditiously to review the use of the new fuel in domestic research and test reactors licensed by NRC.

With respect to future export license applications for HEU, the Commission intends to continue its current practice of careful scrutiny to verify that additional interim HEU exports are justified. According to a timetable prepared by Argonne, only two foreign research reactors should require additional exports of HEU after 1983, and by 1987 the need for HEU exports to essentially all research and test reactors should be eliminated, except possibly certain reactors which may require 45% enriched fuel. The Commission notes these tentative milestones and plans to continue to monitor the progress of the RERTR program so that it can assure that appropriate conversion schedules are met and that actions to eliminate U.S.-supplied inventories of HEU are expedited to the maximum degree possible. [Export license applications for HEU which do not provide adequate justification for continued HEU use, in accordance with achievable conversion schedules, will not receive favorable NRC consideration.]*

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*If the Commission adopts this sentence, it should be recognized that it will have to refer such export applications to the President on the grounds that the Commission is unable to determine that they would not be inimical to the common defense and security. Alternatively, the Commission may wish to have the sentence conclude: "...may not receive favorable NRC consideration". Further, it should be noted that adoption of this policy will require explanation of what new information warrants this position.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
SECRETARY

June 15, 1982

MEMORANDUM FOR: William J. Dircks, Executive Director for Operations

FROM: Samuel J. Chilk, Secretary

SUBJECT: SECY-82-10 - PROPOSED NRC POLICY STATEMENT ON THE USE OF HIGH-ENRICHED URANIUM (HEU) IN RESEARCH REACTORS

PALLADINO	GILINSKY	AHEARNE	ROBERTS	ASSELSTINE
Approved	Approved	Approved	Approved	Approved

July 12, 1982

SECY-82-294

POLICY ISSUE
(Notation Vote)

For: The Commission

From: William J. Dircks
Executive Director for Operations

Subject: HEU POLICY STATEMENT

Purpose: To forward the Executive Branch's comments on the Commission's proposed HEU policy statement and recommend approval of a revised version of the policy paper.

Background: On June 18, in response to a Commission directive, the staff forwarded to the Executive Branch for their information a copy of the Commission's draft HEU policy statement. Our transmittal letter also requested the Executive Branch to confirm by June 25 that adequate funding would be available to continue the reduced enrichment (RERTR) program. On June 23 the staff was advised telephonically by State/OES that the Executive Branch would like to offer certain suggestions to update several technical issues addressed in the proposed paper. We agreed to consider their views if provided promptly, and so informed Chairman Palladino's office. The Executive Branch's comments were received on July 6 and are enclosed at Appendix A. The delay in transmittal was due to State's desire to provide NRC with comments which were fully concurred in by other agencies involved (ACDA and DOE).

Discussion: The staff has reviewed the changes to NRC's HEU policy paper proposed by the Executive Branch and is of the view that they are basically positive and constructive in nature, that they may help to clarify certain points in the policy paper, and that none of the changes would modify or weaken the substance of the policy adopted by the Commission. Consequently, with one exception, the staff recommends that the proposed changes be adopted by the Commission. The one

CONTACT:
Hans Schechter, IP (49-24324)

Discussion (Continued): exception involves a proposed change to the Commission's description of how we utilize Argonne's technical and economic analyses in connection with licensing reviews. Contrary to the procedure referred to in the Executive Branch's proposed changes, the Commission uses the Argonne analyses directly in its licensing reviews.

Detailed staff comments on the Executive Branch's proposed changes are enclosed at Appendix B. For the convenience of the Commission, the staff is enclosing at Appendix C an annotated version of the HEU policy paper incorporating the Executive Branch's comments.

Recommendation: That the Commission approve the revised HEU policy statement at Appendix C.

William J. Dircks
Executive Director for Operations

Appendices:
A - Executive Branch comments
dtd. July 7/1/82
B - Detailed NRC Staff Comments
C - Revised HEU Policy Statement

Commissioners' comments or consent should be provided directly to the Office of the Secretary by c.o.b. Wednesday, July 28, 1982.

Commission Staff Office comments, if any, should be submitted to the Commissioners NLT Wednesday, July 21, 1982, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional time for analytical review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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APPENDIX A

DEPARTMENT OF STATE

BUREAU OF OCEANS AND INTERNATIONAL
ENVIRONMENTAL AND SCIENTIFIC AFFAIRS

July 1, 1982

Mr. James R. Shea
Director
Office of International Programs
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Shea:

Thank you for the advance copy of the NRC policy statement on the use of HEU in Research Reactors. We appreciate the Commission's support for the RERTR program reflected in the statement. However, after consultation with ACDA and DOE, the Department of State believes that the draft contains a few areas where the description of the RERTR program may be outdated. Therefore, we are providing the attached specific comments which would ensure its accuracy and completeness. We believe that, with the changes indicated, the statement will be very useful in implementing the procedures under which U.S.-supplied inventories of HEU can be eliminated to the maximum degree possible.

The RERTR program was initiated by DOE and has been funded and directed by DOE since 1978. It is planned that ACDA will fund the program in FY-83. The technical direction of the program has been, and will continue to be, under DOE's Argonne National Laboratory. OMB has indicated to ACDA that they plan to work with the Congress to make available the necessary funds on an annual basis.

Sincerely,

James B Devine

James B. Devine
Deputy Assistant Secretary

Attachment:

As stated.

Executive Branch Recommendations on NRC Policy Statement on Use of HEU in Research Reactors

The following comments reflect the views of Executive Branch agencies responsible for implementation of the U.S. RERTR program concerning the Commission's draft policy statement. The comments include specific recommended changes in language which we believe would improve the accuracy of the statement.

1. Page 2, para 2, 3 - Combine these paragraphs as follows: The objective of the RERTR program is to develop research and test reactor fuels which will allow substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics or fuel cycle costs. On an interim basis, some reactors may utilize intermediate enrichment fuels (45%), while the LEU fuel development program is in progress. It should be noted, however, that no U.S. effort will be made to develop fuels with enrichments signigicantly below 20%, because of the increasing magnitude of plutonium production in fuels with very low or no enrichment.
   Reason: The near-term and long-term objectives of the RERTR program have essentially coalesced in the last four years, such that a differentiation between them is no longer applicable.

2. Page 3, para 1 - Change lines 1 and 2 to: "To date, DOE has initiated a development and test program managed by the Argonne National Laboratory, to prove," etc.
   Change line 4 to: "Many foreign countries," etc.
   Change line 7 to: ". . . foreign and domestic research reactors."
   Reason: ANL reports to DOE; "many foreign countries" is more accurate than "several foreign countries." licenses have been

issued by the NRC to test fuels in both foreign and domestic research reactors.

3. Page 3, para 2 - Combine with para 2, page 4 as follows: Assuming RERTR program success, most of the performance testing of LEU aluminide and oxide fuels with high uranium densities for use in plate-type reactors will be completed by the end of 1984. The irradiation of pin-type zirconium hydride fuel with high uranium density for use in Triga-type, and possibly plate-type, reactors will be completed in 1983. Assuming licensing approvals, these fuels could then enter into full scale use in appropriate reactors. Silicide fuels with very high uranium densities are also being developed and tested by the RERTR program. These fuels may be needed for conversion of high power reactors.

   Reason: Both page 3, para 2 and page 4, para 2 deal with the technical program schedule. Substantive technical aspects of page 4, para 2 are included in the above suggested combination. Para 2, page 3, as it stands, is limited to low power applications and the phrase "current technology" is confusing. The paragraph needs to be updated and expanded for clarity.

4. Page 3, para 3 - Change line 1 to: ". . . Argonne conducts for DOE a," etc.

   Change line 2 to: "technical and economic evaluation," etc.

   Change line 7 to: "Technical conversion schedules are being planned by reactor operators based on demonstration and licensibility of the fuel"

Add the sentence: Based on the technical and economic evaluation by ANL, a coordinated Executive Branch recommendation on the license application is developed by the Department of State and is submitted to the NRC.

Reason: ANL works for DOE, the evaluation is both technical and economic, and the work flow (see 43 Fed. Reg. 25326) is from ANL to DOE to State, who coordinates and develops the Executive Branch opinion for NRC. Conversion schedules depend on the ability of the reactor operator to obtain a license, as well as fuel availability.

5. Page 3, para 4 - Change line 2 to: "The Commission utilizes the Executive Branch analyses in support of its reviews," etc.
Reason: This sequence is in line with 43 Fed. Reg. 25326. The ANL analyses are part of the input to Executive Branch opinions.

6. Page 4, para 1 - Change sentence 1 to: "The Commission also notes that several types of LEU fuel are currently being tested in DOE's RERTR program."
Change the phrase "all the tests" in line 3 to: "the necessary tests."
Reason: In our view, the suggested changes better describe DOE's operational program.

7. Page 4, para 2 - Eliminate, but combine technical substance with para 2, page 3.
Reason: Para 2, as it stands, states that "in May 1978 GA announced the immediate commercial availability of Triga-type LEU fuel for a large majority of research reactors, which in

GA's opinion, would require only minimal modifications for use of this fuel." Many possible reactor-specific applications of Triga-fuel assemblies in MTR-type reactors would entail significant capital investments for a whole core of Triga-fuel and possibly for "hot" modifications of reactor control and ancillary systems. Many reactor operators show a strong preference for maintaining fuel geometry very similar to that in current use, in order to minimize licensing problems and capital expenditures. Most reactors have cores composed of plate-type fuel elements and plan to convert to LEU plate-type fuel, when the demonstrations are successful. The choice of fuel element belongs to the reactor operator. The concern of the USG is the conversion to a low enrichment fuel, not the fuel element geometry or the manufacturer. There is, also, the difficulty of referencing a manufacturer in a Federal policy statement. While it is true that GA is active in LEU fuel development, there are a number of other manufacturers in Europe and the USA, who are participating in LEU fuel development. The RERTR program currently is supporting test irradiations of the higher-power Triga-LEU fuel assemblies to facilitate future licensing by host governments of conversions to LEU fuels.

It is recommended that the substance of para 2, page 4, namely status of tests on zirconium hydride fuel, be combined with para 2, page 3 as suggested in the comment on the latter.

8. Page 4, para 3, line 2 - Explain the inimicality criterion, or eliminate.

Reason: The phrase "inimicality criterion" is specialized and should be expanded to serve the potential readers of the policy statement

9. In addition to the above, the NPC may wish to consider deletion of the term "U.S.-supplied" from page 1, para 2, line 5, and from page 2, para 1, line 10. Not all HEU inventories abroad are of U.S.-origin.

10. Commissioner Ahearne's Comments

The Executive Branch agrees with the basic thrust of Commissioner Ahearne's comment; namely, that there should be a coherent policy respecting the use of HEU fuels in research reactors, both domestically and in foreign facilities. However, we believe that the statement as written could offer encouragement to foreign reactor operators to delay participation in the RERTR program.

Foreign research reactor operators could plead that U.S. continue to supply them with HEU, until all U.S. research reactors were converted to use of LEU. It should be noted that the RERTR program does not have sufficient funds to support participation by U.S. research reactor operators, apart from the operators of the Ford Nuclear Reactor.

Therefore we would prefer that the statement by altered somewhat, to make the Commissioner's point in a way less likely to produce this negative reaction by foreign operators. For example, the statement could simply say: "Commissioner Ahearne believes that there should be more involvement by U.S. research reactor operators in the conversion of their reactors to use of LEU fuels.

APPENDIX B

Detailed NRC Staff Comments on Executive Branch Recommendations

1. The staff has no reason to doubt or question the accuracy of the technical points made in items 1, 3, 4 and 7.

2. The first point of item 2 addresses essentially procedural or organizational matters concerning the RERTR program and is acceptable.
   The second point it item 2 is primarily of an editorial nature and is acceptable.

   Inclusion of "domestic" (third point in item 2) is acceptable.

3. The staff disagrees with the proposed change in item 5 since the Commission uses the ANL analyses directly in its review of HEU export license applications.

4. The staff has no problem with the first point in item 6, and believes that use of the word necessary in the second point of item 6 is in fact more correct.

5. Regarding the clause on inimicality in item 8, the staff supports the inclusion of an alternate phrasing of the clause as follows, "bearing in mind the Commission's responsibility to make an overall finding that each export would not be inimical to the common defense and security of the U.S.".

6. The staff agrees with the deletion proposed in item 9.

7. The staff defers to Commissioner Ahearne regarding the Executive Branch's comments in item 10 on his proposed statement.

APPENDIX C

NRC Policy Statement on the Use of High-Enriched Uranium (HEU) in Research Reactors

(Executive Branch changes annotated)

In the 1950's the U.S. entered into several short-term agreements for cooperation (5-10 years) allowing for the export of research reactors and fuel under the "Atoms for Peace" program. In subsequent years the U.S. has been a major supplier of high-enriched uranium (HEU) for use abroad, primarily in research and test reactors. Such reactors produce radicisotopes for use in such areas as medicine, agriculture, desalination, research in biological effects of radiation, etc. Materials test reactors are also used to train future operators of commercial power reactors and to test new materials and fuels.

In the mid-1970's, particularly following India's detonation of a nuclear explosive device in 1974, nuclear proliferation concerns began to increase. Expanded efforts were undertaken to prevent nuclear power programs from being exploited to produce nuclear weapons. Particular concerns were expressed with respect to the proliferation risks associated with ~~U.S.-supplied~~ inventories of HEU for research and test reactors abroad. The widespread use of HEU fuel, which involved a large number of domestic and international fuel shipments, increases the risks of proliferation through theft or diversion of this material. In contrast to HEU, the use of fuel with lower enrichments reduces proliferation risks.

In an effort to allay concerns of proliferation risks, efforts were made to reduce HEU inventories, on the assumption that any reduction in the potential for access to these inventories would constitute a reduction in the proliferation risk. These concerns eventually led to the establishment of the reduced enrichment for research and test reactors (RERTR) program. This program was established to develop and demonstrate the technology that will facilitate the use of reduced-enrichment uranium fuels in research and test reactors. If seccessful, this could led to a significant reduction of ~~U.S.-supplied~~ HEU-inventories abroad, and thereby increase the proliferation resistance of related fuel cycles.

The objective of the RERTR programs is to develop research and test reactor fuels which will allow substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics or fuel cycle costs. On an interim basis, some reactors may utilize intermediate enrichment fuels (45%), while the LEU fuel development program is in progress. It should be noted, however, that no U.S. effort will be made to develop fuels with enrichments significantly below 20%, because of the increasing magnitude of plutonium production in fuels with very low or no enrichment.

~~The near term objective of the program is to use current technology to achieve the lowest feasible fuel enrichment for readily convertible research reactors. Fuel fabrication technology is expected to permit enrichment reduction from 90-93% to 30-45% in many MTR fuel design without a reduction in reactor performance.~~

~~The long term goal of the RERTR program is to develop research and test reactor fuels which will allow substitution of uranium of lower enrichment for HEU and will not significantly affect reactor performance characteristics. It whould be noted, however, that no U.S. effort will be made to develop fuels with enrichments significantly below 20% because of the increasing magnitude of plutonium production in fuels with very low or no enrichment.~~

To date, DOE ~~under the programs direction of Argonne National Laboratory, has initiated a development and test program to~~ has initiated a development and test program managed by the Argonne National Laboratory, to prove the feasibility of the new lower enrichment fuels. ~~Several~~ Many foreign countries are cooperating with the U.S. in this effort, and, within the past year, NRC has issued several export licenses for reduced-enrichment uranium to be fabricated into test elements for foreign and domestic research reactors.

Assuming RERTR program success, most of the performance testing of LEU aluminide and oxide fuels with high uranium densities for use in plate-type reactors will be completed by the end of 1984. The irradiation of pin-type zirconium hydride fuel with high uranium density for use in Triga-type, and possibly plate-type, reactors will be completed in 1983. Assuming licensing approvals, these fuels could then enter into full scale use in appropriate reactors. Silicide fuels with very high uranium densities are also being developed and tested by the RERTR program. These fuels may be needed for conversion of high power reactors.

~~Assuming RERTR program success, most of the performance testing of "current technology" LEU fuel (for low power reactor applications) will be completed by 1984, after which the LEU aluminide oxide fuels, assuming licensing approvals, could enter into full scale use in appropriate reactors.~~

As part of the overall RERTR program, Argonne conducts for DOE a technical and economic evaluation of each significant HEU export license application including the potential of the reactor for conversion to reduced-enrichment fuel within the planned availabilities of appropriate reduced-enrichment fuels. Nearly all potential conversion candidates have been evaluated. ~~and tentative~~ Technical conversion schedules ~~proposed,~~ are being planned by reactor operators based on demonstration and licensability of the fuel. Based on the technical and economic evaluation by ANL, a coordinated Executive Branch recommendation on the license application is developed by the Department of State and is submitted to the NRC.

The objectives of the RERTR program have been fully supported by NRC since its inception. The Commission has also utilized Argonne's analyses in support of its reviews of proposed interim exports of HEU, particularly with respect to determining the dates when conversion to lower-enriched fuels can be anticipated. The Commission is pleased to note that the current Administration continues to support the RERTR program and that Congress has approved adequate funding for the program.

The Commission also notes ~~DOE's commitment of some of its own research and test reactors to demonstration of the use of lower enrichment fuel.~~ that several types of LEU fuel are currently being tested in DOE's RERTR program. As soon as all the tests are completed, the Commission is prepared to act expeditiously to review the use of the new fuel in domestic research and test reactors licensed by NRC.

~~The Commission notes further that as long ago as 1976, General Atomics (GA) began a program of developing LEU research reactor fuels for pow rs of up to 15 MW in reactors using plate type as well as those using Triga fuel. At the IAEA meeting on Research Reactor Renewal and Upgrading held in May 1978, GA announced the immediate commercial availability of Triga type LEU fuel for a large majority of research reactors, which in GA's opinion, would require only minimal modifications for the use of this fuel. At the present time, the NRC staff is unable to say whether or not testing of the fuel will be required for licensing.~~

With respect to future export license applications for HEU, ~~using the inimicality criterion,~~ bearing in mind the Commission's responsibility to make an overall finding that each export would not be inimical to the common defense and security of the U.S., the Commission intends to continue its current practice of careful scrutiny to verify that additional interim HEU exports are justified. The Commission plans to continue to monitor the progress of the RERTR program so that it can understand what would be appropriate conversion schedules, and to encourage that actions be taken to eliminate U.S.-supplied inventories of HEU to the maximum degree possible.

Commissioner Ahearne notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. He believes the Commission should first address whether all U.S. research reactor operators must convert to lower enrichment fuel before insisting that foreign operators do so.

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

O. K. HARLING
Director

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L. CLARK, JR
Director of Reactor Operations

November 24, 1982

The Honorable Nunzio J. Palladino, Chairman
United States Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Chairman Palladino:

The managers of Test, Research and Training Reactors (TRTR) have requested me to write to you on their behalf concerning the application of the Commission's policy on the Use of High Enriched Uranium (HEU) in Research Reactors, as expressed in the Federal Register (FR 37007) on August 24, 1982.

The TRTR managers group met in College Station, Texas on October 18-20, at which time the NRC policy statement was among many topics discussed. It is our hope the TRTR can commence a dialogue with appropriate commission representatives with regard to guidelines that we assume will be developed for application of the policy on continued use of HEU.

The TRTR community believes that the following considerations rank high among those that must be evaluated in developing guidelines and that this community is in a forefront position to provide assistance in these areas.

1. The licensability of higher fuel loadings and new compositions.
2. Reasonable schedules for implementation of the policy.
3. The initial costs associated with converting a reactor to new fuel and subsequently the fuel cycle costs associated with utilization of the new fuel.
4. Sources of funding to cover these costs.
5. The extent to which present and future forefront research may be inhibited by conversion as the result of performance limitations.
6. The impact of HEU policy guidelines on low power reactors whose present fuel is expected to last for many years, in some cases for the life of the reactor, including the cost of reprocessing partially spent fuel if replacement is required.

The wide variations in reactor types, in power levels and in other respects emphasizes the need for input from the TRTR group in an undertaking that will have such a broad impact on the many disciplines in the life and physical sciences and related technologies served by the TRTR reactors. We hope for a continuation of the interaction that has been developed between NRC and the research reactor community on the subject of emergency plans, as most recently exemplified by the October 15-17 meeting at the Texas A&M Nuclear Science Center to review the Standard Review Plan, NUREG-0849. We urge that a similar cooperative effort be launched in the area of HEU utilization in reactor fuel, but that the dialogue commence at a much earlier stage than was the case for emergency plans.

In conclusion, before or at such time as NRC starts to develop a policy regarding continued use of HEU fuels by U.S. research reactors, input from the TRTR community should be sought. We propose an initial meeting at that time between responsible NRC and TRTR representatives to review our concerns, including the six listed above, to be followed by some form of continuing dialogue. The Commission's estimate as to when such a meeting will be useful will enable TRTR to make appropriate plans.

Thank you for your consideration of this request. A list of TRTR member reactors is attached.

Sincerely,

Lincoln Clark Jr.

Lincoln Clark, Jr.
Chairman, TRTR

LC/sbs

cc: TRTR Members

10/17/82

National Organization of Test, Research and Training Reactors
List of TRTR Member Reactors

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

April 21, 1983

Dr. Lincoln Clark, Jr.
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Cambridge, Massachusetts 02139

Dear Dr. Clark:

Pursuant to our conversation in Philadelphia last week, I am sending you a copy of the paper which the Office of Policy Evaluation sent to the Commissioners on the subject of reducing enrichment at research reactors. You should be aware that the Commissioners have not yet taken any action on the recommendations. We envision that the proposal to permit refuelling with low enriched uranium, should the Commissioners approve such an action, would be effected through rulemaking. Licensees therefore would have ample opportunity to comment on the proposed change.

Sincerely,

George P. Eysymontt
Assistant to Director, OPE

Enclosure:
As Stated

F

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

March 1, 1983

MEMORANDUM FOR: Commissioner Ahearne

FROM: John E. Zerbe

SUBJECT: POLICY TO REDUCE ENRICHMENT AT DOMESTIC RESEARCH AND TEST REACTORS

Attached is a brief paper prepared at your request. It proposes several options for encouraging domestic research and test reactors to use low enriched uranium fuel. The NRC licensing staff has had several opportunities to review this paper. The various options have also been discussed in general terms with the National Organization of Test, Research and Training Reactors whose representatives met with the staff and OPE earlier this month. In addition, the paper has been informally reviewed by the Departments of State and Energy.

I recommend that the Commission pursue two of the options that have been proposed:

(1) that no new research reactors be licensed for use of HEU fuel unless the applicant shows that the unique purpose of the project could not be achieved without using HEU fuel.

(2) that existing reactors must replace burned up HEU fuel with LEU if technically feasible with existing fuel technology at the time of refueling.

Should the Commission wish to pursue these options, OPE is ready to work with the staff to see that the policies are put into place.

Attachment:
As Stated

cc: Chairman Palladino
Commissioner Gilinsky
Commissioner Roberts
Commissioner Asselstine
Herzel Plaine
Samuel J. Chilk
William J. Dircks

CONTACT:
George Eysymontt (OPE)
634-3302

POLICY TO REDUCE ENRICHMENT AT RESEARCH AND TEST REACTORS

For some time there has been concern about the proliferation risks associated with inventories of highly enriched uranium used in research and test reactors abroad. In August, 1982, the Commission issued a policy statement expressing its concern and indicating support for the conversion of foreign reactors to low enriched uranium. In conjunction with the issuance of this policy statement Commissioner Ahearne noted that the Commission had committed itself to get U.S. licensees to move to lower enrichment fuel and requested that the Office of Policy Evaluation develop a program plan outlining appropriate steps to maintain the same level of pressure on U.S. licensees as the Commission intends to maintain on foreign users of U.S. fuel. This paper summarizes the current situation in the United States and suggests some policy options which the Commission may wish to pursue in order to achieve this objective.

Current Situation

In its annual report[1/] to the Congress, the Department of State summarized the current situation with respect to highly enriched uranium as follows:

> The United States is the principal exporter of highly enriched uranium for use as fuel in research and test reactors. Forty-seven such reactors abroad, with powers of 1 MW or more, currently use HEU of United States origin, as do 22 reactors[2/] of that type and size in the United States. Exports of HEU for use in the foreign reactors average about 600 kilograms annually; about 500 kilograms are used domestically. Since

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[1/] Report to the Congress pursuant to Section 601 of the Nuclear Non-Proliferation Act of 1978.

[2/] Includes DOE reactors not licensed by NRC.

> the duration of the fuel cycles, from the export or domestic delivery of fresh HEU to the return of spent fuel, averages about four years, approximately 4,400 kilograms of HEU of United States origin are in circulation at any given time, for research reactor use alone, in the United States and abroad.

There are 28 NRC-licensed research and test reactor facilities of all sizes, mostly university operated, which presently may use highly enriched uranium [HEU]. Only 16 of these facilities are currently authorized to possess a formula quantity of HEU. Of these 16, seven are 1 MW or less, and nine are greater than 1 MW. The total capacity of NRC-licensed research and test reactor facilities using HEU is approximately 50 MW. In addition to these facilities there are 15 Department of Energy research and test reactors totalling some 450 MW and 1 U. S. power reactor (Ft. St. Vrain) which also utilize HEU. Table 1 and 2 attached indicate the location of each research and test reactor licensed by NRC which may use HEU and show the authorized level of fuel which the licensee may possess.

Because the high cost of construction and operation and relatively low student enrollment in the nuclear departments of universities, the staff does not expect to receive any new license applications for research reactors in the near future. Following the issuance of the present backlog of 20 license renewal applications, there will be 1 to 4 renewals processed annually with renewals issued typically for 20 years.3/ Most of the research reactors are not refueled often due to low usage and consequently low burn-up. At these current rates many licensees expect to use their present cores for the rest of this century.

3/The licensing backlog includes research and test reactors which use either LEU or HEU. There are 66 NRC-licensed research and test reactors.

Conversion to Low Enriched Uranium Fuels

In 1978 the United States government established the Reduced Enrichment for Research and Test Reactors (RERTF) program. The RERTR program is administered by the Department of Energy (DOE), with the bulk of the technical responsibility centered at the Argonne National Laboratory (ANL). The goal of this program is to substantially minimize the trade in HEU (HEU, containing greater than 20% U-235) by developing and demonstrating new high uranium density fuels to permit reactor conversions to the use of low enriched uranium (LEU, containing less than 20% U-235).

In assessing the practical feasibility of utilizing low enriched uranium fuel in existing research reactors, the DOE RERTR Program is using the following criteria: safety margins and fuel reliability should not be lower than for the current design based on highly enriched uranium; major reactor modifications should not be required; and the loss in overall reactor performance (i. e., flux per unit of power) as well as the increase in operation costs should be minimized.

Enrichment reduction by simple substitution of lower enriched uranium in existing fuel designs has the immediate effect of reducing core performance and cannot meet the above criteria. Enrichment reductions can be feasible for most research and test reactor designs if the U-235 content in the fuel element is increased while the enrichment is decreased. Irradiation performance, in terms of flux per unit of power, can remain comparable to that attained with HEU fuel. The neutron poisoning effect of the U-238 contained in LEU-fuel must be compensated to maintain reactivity, fuel life and reactor performance.

For plate-type fuel the necessary increase in uranium content per fuel element could be achieved by increasing the volume fraction of the fuel meat and/or by increasing the uranium concentration in the fuel meat. Increasing the volume fraction of the fuel meat can be accomplished by decreasing the plate clad thickness and increasing the meat thickness or by using a smaller number of thicker plates per element. Either route must avoid any unnecessary decrease in coolant volume. Each approach has limitations which make it difficult to adequately increase the fuel meat volume fraction in high-performance reactors that operate very close to their thermal-hydraulic limit with their present HEU fuel.

If the uranium concentration in the fuel meat could be adequately increased without changing the thickness, it would have negligible effects on the thermal-hydraulics properties of the core. The implementation of this approach is tied to the development and demonstration of fuel materials offering significantly higher uranium density using advanced fuel fabrication technology. Development of new fuel material, appropriate fabrication techniques and irradiation testing of the fuel is currently underway in the U. S. under the auspices of the RERTR program and in complementary programs of various foreign countries.

The Department of Energy program to achieve this goal is a two-phased fuel development, testing and demonstration effort. Phase I involves production and testing of aluminide- and oxide-dispersion LEU-fuels with maximum achievable uranium densities, using best available commercial technology for fuel fabrication. These "current technology" LEU-fuels are limited in service to the lower power reactor applications, such as the on-going fuel core demonstration of LEU fuel in the 2MW Ford Nuclear Research Reactor at the University of Michigan.

To date, Phase II activities have included: selection of uranium silicide as a candidate material capable of providing significant increase in uranium density for the fuel meat; production and extensive irradiation of miniplates (clad fuel specimens) of silicide-dispersion fuel materials; production and initiation of testing of full size prototype fuel assemblies in selected test reactors; and initiation of post irradiation examinations of miniplates irradiated to as high as 80% burnup of fissile content.

Future Phase II activities include: completion of post irradiation examinations on most of the irradiated LEU-fuel miniplates (and any other specimens which might be deemed necessary); and selection of the preferred uranium silicide dispersion material for fabrication into LEU-fuel for a full core demonstration in a high performance reactor such as the Oak Ridge Research Reactor. Such a commercial procurement and irradiation performance demonstration is planned during the period FYs 1985-88. At this time, the RERTR program has completed too few post irradiation evaluations to quantitatively assess the performance of the highest U-density silicide fuel candidates.

NRC must review the irradiation performance data generated in the LEU-fuel test programs of DOE and its partners abroad, as a basis for establishing licensibility of the resulting LEU-fuels. Appropriate safety analysis reports must be completed for each specific reactor application before LEU replacement cores could be licensed for use in the related research and test reactors. If approved, a license amendment could be issued for the specific LEU-fuel application in accordance with normal licensing procedures.

Policy Options

The following discussion assumes that a principal concern of U.S. policy with respect to HEU use abroad is the threat of national diversion. Thus, the goal of U.S. policy is to stop all international traffic of HEU and the purpose of this paper is to discuss domestic policy options which comport with this objective. To further this goal, it is important that the U.S.

have a domestic policy on HEU reduction comparable to its overseas policy. Otherwise, it has been argued, foreign operators will be reluctant to convert to the use of LEU and could claim the U.S. was trying to gain an advantage in nuclear technology and research.

There are a number of steps which the NRC could take to help achieve this U.S. non-proliferation policy objective. There are also a number of other steps which could be taken by other agencies to encourage conversion of non-power reactors to LEU. These are all discussed below with an indication as to who might be affected and how the policy might be implemented. In the discussion below it is assumed that current U.S. physical protection regulations are sufficient to counter domestic threats and that the primary purpose of the initiative is to encourage conversion of foreign facilities.

Option 1: No new research reactors would be licensed for the use of HEU fuel unless the applicant showed that the unique purpose of the project could not be achieved without using HEU-fuel.

The Commission could issue a policy statement which would state that the NRC would no longer consider applications for a construction permit to build non-power facilities utilizing HEU unless the applicant could show that the objective of the project could not be met using LEU fuel. This probably will not affect any one immediately since the staff does not believe there are any such applications contemplated at present. It would send a message to users of HEU that the U.S. is taking steps to limit the use of HEU. This option has been formulated to require justification for HEU fuel use to take into account comments received during a recent meeting held by the staff and the Office of Policy Evaluation with the National Organization of Test, Research and Training Reactors. This group felt that a policy of absolute prohibition of new research reactors using HEU could be damaging to U.S. research in reactor and fuel technology. In addition, the State Department has informed us after an informal review of this paper that in its formulation of the RERTR program, the U.S. has reserved the right to build new domestic research reactors using HEU, if the mission justifies it. Apparently, France, the USSR, and the U.K. maintain the same option.

Option 2: Existing reactors must replace burned up HEU fuel with LEU, if technically feasible with existing fuel technology at the time of refueling.

The Commission could issue a rule prohibiting those research reactors which could use LEU from refueling with HEU unless licensees demonstrated that it would not be technically feasible to use LEU fuel in the reactor or, alternatively, that the appropriate LEU fuel was unavailable from fuel fabricators. The basis for the prohibition would be that it is in accord with U.S. policy with respect to exports of HEU to non-power reactors abroad. The consequences of such an approach is far reaching but gradual. There are twenty-eight research and test reactors potentially convertible to low enriched uranium fuel. This would immediately affect all five TRIGA-type reactors as well as three plate-type reactors (University of Michigan, Rhode Island NSC, University of Lowell [Mass.]). As matters now stand, General Atomics is the sole source fuel fabricator for TRIGA reactors and it no longer fabricates HEU fuel for these reactors. Only LEU fuel is available, so TRIGA users no longer have any choice but to replace their HEU elements gradually with LEU as their current fuel is burned up. Licensing is not a problem since the technical specifications for these facilities already permit operation using LEU. While these users have no choice but to convert, due to their low utilization rates it may take a long time.

The situation with respect to the 3 plate-type reactors is that a full-core LEU demonstration is on-going at the University of Michigan reactor using 1.7 gm/cc density fuel. Although incomplete, this test shows promise for complete success. The Rhode Island NSC and University of Lowell reactors could convert to similar LEU fuel as their current HEU fuel is burned up, assuming no safety problems arise in the course of NRC's licensing reviews. The on-going full core demonstration has indicated that mixed HEU-LEU cores are both technically and economically feasible for such reactor applications.

If adopted, a rule prohibiting research reactors from being refueled with HEU if capable of using LEU would result in a gradual reduction in the HEU content of the cores of research reactors. Table I and II summarize the current fuel conversion situation with respect to research and test reactors for sizes greater than and less than one MW respectively. Most reactors it appears must await the successful development of silicide fuels which are not expected to be available until the late 1980's. For reactors less than one MW, based on current usage rates, existing cores will probably never have to be replaced during the life of the reactor. Consequently, this option would not affect many small reactors which are owned by universities.

Option 3: Immediate replacement of the cores of those existing reactors capable of using LEU.

Under Option 2, the process of conversion of those reactors where conversion is feasible would be gradual due to the low rates of burn-up. An alternative to this approach would need a more radical change in federal policy and in the availability of federal funds. If the Commission believes that it is important to achieve domestic conversions more rapidly than in the previous alternative, then additional steps need to be taken to assist in the conversion of fuel inventories or face the prospect that these reactors would be shut down because operators could not comply due to lack of funds.

A more radical approach than the policy proposed in Option 2 would be for the Commission to push for immediate conversion of fuel inventories to LEU only. Of those reactors greater than 1 MW, this would affect five TRIGA reactors immediately and two plate-type reactors (Rhode Island and Lowell), given the successful use of LEU fuel at the University of Michigan reactor. Michigan already has a complete LEU core. The other potentially convertible reactors must await the successful development of silicide fuels. Based on the current RERTR schedule, high density silicide fuel will not be available for a full core demonstration for another three to five years.

As for the fourteen reactors which are less than 1 MW in size, according to analyses done by Argonne National Laboratory, there are four which could be converted to oxide fuel and two to aluminide fuels with current technology (see Table II). Should the Commission decide to pursue this option, consideration should be given to excluding reactors possessing less than a formula quantity of strategic special nuclear from the requirement to immediately replace their existing fuel inventories. This would mean fewer funds would be needed to effect the necessary inventory exchange. While this approach may be practical from a domestic point of view, the State Department has indicated that this is not their approach with respect to exports of HEU to foreign reactors. They would like to see all commerce in HEU stop.

If the Commission believes that it is important to achieve complete fuel inventory conversion more rapidly than in previous alternatives, then additional steps need to be taken to assist in that conversion. The Department of Energy, the Office of Management and Budget, and appropriate Congressional Committees would have to be convinced to provide funds at least to assist in the conversion, and to procure the fabricated fuel cores. It should be noted that current U.S. policy does not propose immediate conversion of facilities using U.S.-supplied HEU abroad. Given the state of university finances and present enrollments in nuclear departments, immediate conversion without financial support from the government could well result in closing of these facilities. Should government funding not be available to private industry for complete conversion, it is unclear what action they would take.

At present all university-owned reactors receive their fuel from the Department of Energy through the University Reactor Fuel Assistance Program (URFA). The fuel is D.O.E. owned. The transportation costs to the reactor is an important factor in the cost of the fuel, and URFA does not necessarily pay for it. DOE presently absorbs the cost of reprocessing this fuel, but not out of the URFA budget which totalled $1.6 million in FY 82.

The cost of a new core is difficult to estimate since fabrication costs are a function of the technology, basic fuel costs, and throughput of the fabrication facility. However, for order of magnitude purposes, a fabrication cost of $25,000 per fuel element can be assumed. Since a typical (1 MW) research reactor has about 30 elements, it implies that it would cost about $750,000 for fuel to immediately replace an existing core. Added to this must be facility modifications (if any), shipping, storage and reprocessing costs. Costs for a complete conversion are estimated to range from $1 to $1.5 million per reactor core. As a percent of the URFA budget, the cost of conversion would be large. As a percent of the DOE budget, the cost would be miniscule.

Option 4: Conversion of DOE facilities utilizing HEU to LEU.

As pointed out earlier, the total capacity of DOE facilities using HEU exceeds that licensed by NRC by about a factor of 9. Because of a greater degree of reactor utilization by DOE as compared with NRC-licensed research and test reactors, the replacement of HEU reactor fuel with LEU fuel as it is burned up may be more rapidly implemented. On this point it should be noted that of the 450 MW operated by DOE, five reactors represent the bulk (440 MW) of the capacity. One of these reactors has a capacity of 250 MW and is currently being used for defense-related research. Moreover, at least three of these reactors totalling 410 MW could not be converted at present because they require successful development of silicide fuels. Therefore, while it is possible that DOE facilities could be used for demonstrating the country's resolve to convert its facilities to LEU in support of international policies on non-proliferation, it does not appear that a significant portion of the capacity operated by DOE could be rapidly converted given the nature of the facilities.

TABLE II
POTENTIALLY CONVERTIBLE
DOMESTIC RESEARCH AND TEST REACTORS
LESS THAN 1 MW PRESENTLY USING HEU
GREATER THAN 70%

Reactor Location	Power MW	Auth. Fuel Kg.	Exp. Date	Comment
1. Virginia Polytechnic Instit.	0.1	8.0	2002	Could convert to oxide fuel 1/
2. University of Missouri (Rolla)	0.2	4.3	2003 3/	Status Unknown
3. UCLA	0.1	4.9	2003 3/	Could convert to oxide fuel 1/
4. Manahattan College	0.0001	3.2	1984	Status Unknown
5. University of Kansas	0.25	4.0	2003 3/	Approx. annual burnup 2%. 2/
6. Iowa State University	0.01	4.6	2003 3/	Approx. annual burnup 2%. 2/
7. Worcester Polytechnic Instit.	0.01	4.0	2002	Could convert to aluminide fuel 1/
8. Ohio State University	0.01	4.6	2000	Could convert to oxide fuel 1/
9. University of Washington	0.1	7.5	1989	Could convert to oxide fuel 1/
10. Purdue University	0.01	3.0	1986	Could convert to aluminide fuel 1/
11. University of Florida	0.1	4.8	2002	Converting to 3% LEU.
12. Rensselaer Polytechnic Institute	0.0001	5	2003 3/	Approx. Annual Burnup 2%. 2/
13. Westinghouse (Illinois)	0.01	8.1	2004 3/	Approx. Annual Burnup 2%. 2/
14. University of Calif. (Santa Barbara)	0.000001	1.4	1994	Approx. annual burnup 2%. 2/

1/ According to Argonne National Laboratory analysis

2/ Must await development of silicide fuels

3/ Relicense applications pending. Renewal projected to be approved for date shown.

TABLE 1
POTENTIALLY CONVERTIBLE
DOMESTIC RESEARCH AND TEST REACTORS
GREATER THAN 1 MW PRESENTLY USING HEU
GREATER THAN 70%

Reactor Location	Power MW	Auth. Fuel Kg.	Annual U-235 Reqmnt.	Minimum LEU Density		Lic. Exp. Date	Comment
				No Geom. Change	Geometry Change		
TRIGA-Type Reactors:							
1. Oregon State University	1	16.3[1]	0.07	1.3	-	2002	General Atomics no longer manufactures HEU fuel, but they do manufacture LEU fuel. These reactors currently have mixed HEU-LEU cores.
2. Washington State Univ.	1	19.9[1]	0.04	1.3	-	2002	
3. Univ. of Wisconsin	1	13.7[1]	0.11	1.3	-	2000	
4. Texas A & M	1	17.2	0.18	1.3	-	2002	
5. General Atomics(La Jolla)	1.5	35.0	0.02	1.3	-	2000	
Plate-type Reactors:							
1. Nat'l Bureau of Standards	10	45.0	12.9	5.6	?	2003[1]	May be convertible using silicide fuels
2. University of Missouri	10	45.0	18.7	5.6	?	2001	Must await silicide fuel development.
3. Union Carbide (New York)	5	40.0	5.4	3.7	3.1	2003[1]	
4. M.I.T. Research Reactor	5	29.0	5.4	8.7	?	1996	
5. Georgia Tech Research Reactor	5	13.5	1.9	3.4	?	1994	
6. Ford Nuclear Reactor (Univ. of Michigan)	2	16.1	3.3	-	1.7	1985	Full-core LEU demo on-going[2]
7. Rhode Island NSC	2	10.4	2.5	3.9	1.7	2002	Poss. conv. after U. Mich. demo.
8. Univ. of Virginia Reactor	2	17.6	1.3	3.3	3.1	2002	Must await med. dens. oxide fuel dev.
9. University of Lowell (Mass.)	1	4.8	0.2	3.4	1.7	1985	Poss. conv. after U. Mich. demo.

[1] Relicense applications pending. Renewal projected to be approved for date shown.
[2] low density oxide fuel

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
SECRETARY

June 21, 1983

MEMORANDUM FOR: William J. Dircks, Executive Director for Operations

FROM: Samuel J. Chilk, Secretary

SUBJECT: PROPOSED COMMISSION POLICY TO REDUCE ENRICHMENT AT DOMESTIC RESEARCH REACTORS

The Commission (with all Commissioners agreeing) has agreed that a proposed rule be developed with the following provisions:

(1) No new research or test reactors be licensed for use of HEU fuel unless the applicant shows that the unique purposes of the project cannot be achieved without using HEU fuel.

(2) At each refueling, existing research and test reactors must replace burned up HEU fuel with fuel having appreciably lower enrichment than the original,

 (a) if that would be technically feasible with existing fuel technology at the time of refueling, and

 (b) unless the license shows that the unique purposes of the project could not be achieved without using HEU fuel.

(3) Both (1) and (2) are based on Congress funding DOE to provide the appreciably lower enrichment and LEU fuel for university reactors.

The rulemaking should also request comments as to what extent economic feasibility should influence (1) and (2).

The Office of International Programs should also keep the State Department informed.

You should develop the proposed rule with help from OPE and return it for final Commission action.
(EDO) (SECY Suspense: 8/15/83)

Chairman Palladino, while agreeing to have the staff begin development of the proposed rule, is not convinced at this time of the need for the rule. He would expect to have the staff brief the Commission on this matter before extensive efforts are expended in developing the proposed rule.

Commissioner Gilinsky adds: "The proposed rule, as described in this SRM, would allow research reactor owners to continue to fuel their reactors with highly-enriched uranium -- a nuclear explosive -- by claiming that the unique purpose of their project requires HEU. The SRM also states that the proposed rule should ask for comments on the economics of switching from HEU to LEU. I would like the Commission to adopt a stronger rule which would not allow any new civilian reactors to be licensed using nuclear explosive fuel, regardless of the purpose. I would also not consider economics as a strong basis for allowing continued use of HEU (nuclear explosive) fuel in existing reactors.

"The Commission's lax approach is inconsistent with its policy statement on HEU, which was intended to encourage research reactor owners abroad to use lower enrichment fuel instead of HEU to cut down on exports of that dangerous nuclear explosive material. The loopholes that would allow U.S. reactors a pretext not to switch will influence owners of foreign research reactors."

cc: Chairman Palladino
    Commissioner Gilinsky
    Commissioner Ahearne
    Commissioner Roberts
    Commissioner Asselstine
    OGC
    OPE

UNITED STATES NUCLEAR REGULATORY COMMISSION

August 19, 1983

SECY-83-349

RULEMAKING ISSUE
(Information)

For: The Commissioners

From: William J. Dircks
Executive Director for Operations

Subject: PLANS FOR DEVELOPMENT OF PROPOSED RULE ON HEU FUEL AT DOMESTIC RESEARCH REACTORS

Purpose: To inform the Commission of the staff's plans and schedule for developing the proposed rule.

Discussion: The Secretary's memorandum of June 21, 1983, to the EDO, indicated Commission agreement to a proposed rule to be developed by the staff "with help from OPE" with the following provisions:

(1) No new research or test reactors will be licensed for use of HEU fuel unless the applicant shows that the unique purposes of the project cannot be achieved without using HEU fuel.

(2) At each refueling, existing research and test reactor licensees must replace burned up HEU fuel with fuel having appreciably lower enrichment than the original,

  (a) if that would be technically feasible with existing fuel technology at the time of refueling, and

  (b) unless the licensee shows that the unique purposes of the project could not be achieved without using HEU fuel.

(3) Both (1) and (2) are based on Congress funding DOE to provide the appreciably lower enrichment and LEU fuel for university reactors.

The staff is gathering two principal types of information for use in drafting the proposed rule and possible options. analysis of technical impacts, and analysis of regulatory impacts.

Contact:
Charles Kelber, RES
427-4442

A considerable amount of analysis of technical impacts has been performed by the Departments of Energy and State under the "U.S. Reduced Enrichment Research and Test Reactor (RERTR)" program. The goal of this program is to develop and qualify for licensing fuel fabrication techniques which allow the use of low enrichment fuel in place of high enrichment fuels at research and test reactors. Although the focus is on U.S. reactors and licensing practice, there is extensive foreign interest, expressed through the State Department.

Earlier this year the Office of Policy Evaluation provided the Commission a memorandum (Zerbe to Commissioner Ahearne, March 1, 1983) summarizing the current situation with respect to the U.S. use of HEU in research and test reactors. After reading the material supplied by OPE and subsequently meeting with key personnel from OPE and DOE, the staff proposed to focus its impact analyses on the class of university operated research and test reactors, of which there are 14,that are authorized to possess a formula quantity of highly enriched uranium (HEU). Two other research reactors that are NRC-licensed facilities fall in this category-the National Bureau of Standards reactor at Gaithersburg, MD, and the Union Carbide Research Reactor in New York. No analysis is planned for these facilities since each appears to be a special case with significant institutional support. The university reactors traditionally receive support for fuel procurement from DOE; however, DOE will not support the procurement of HEU fuel for universities if a feasible LEU fuel can be made available.

The technical impact is to be assessed by combining the data gathered by DOE and OPE with data gathered by a task force of representatives of the Nuclear Engineering Department Heads Organization (NEDHO), under a contract with Renssalaer Polytechnic Institute. This contract is for a short (ca. three months) study to determine:

1. The compatability of the schedule of research and development on LEU fuels with the anticipated realistic schedule of research reactor refueling and operational schedules.

2. The technical problems encountered in converting to LEU fuel. While this currently appears to be feasible for reactors that can use low density LEU fuel, such as at the Ford Reactor at the University of Michigan, administrators at the more advanced reactor facilities have stated that this or even higher density LEU fuels will not be useable in their respective reactors.

3. The licensing problems associated with LEU fuel will be identified and assessed, primarily to estimate the type of licensing amendment needed under current rules.

4. The impact of conversion to LEU fuel on research reactor functions will be examined including effects on research, training, and testing programs including effects on the potential safety hazards of in-pile tests.

The staff recognizes that the Nuclear Engineering Department Head Organization (NEDHO) has a high degree of concern with the proposed rule and that this concern will undoubtedly be reflected in portions of the study. On the other hand, the staff knows of no other practical way to develop the knowledge required to assess the impacts, and feels that, with the independent basis generated by DOE as well as the OPE analysis, there is sufficient basis to render a dispassionate synthesis of the information.

The National Organization of Test Research and Training Reactors (TRTR) has cross-membership with NEDHO and their views will be recognized in the study group report; but TRTR, as an organization, may wish to comment separately as they already have in the letter to Chairman Palladino, dated July 27, 1983.

The analysis of the regulatory impacts will be carried out by RES and NRR with consultation with ELD and OPE. Major attention will be paid to considerations involved in provisions for the Standards and Conditions for Licenses and Construction Permits, and the process for Amendment of Licenses. The key sections of 10CFR 50 are: 41, 45, 54, 55, 59, and 90. The analysis will seek to answer to such questions as: what type of license amendment is required, what conditions indicate the need to reapply for a construction permit, when are modifications insubstantial, and should a regulatory guide be issued to cover the process of amending the licenses to operation with LEU fuel? The extent of economic impacts will be studied under the technical analysis; regulatory implications of such impacts will be analysed and reported.

Other matters to be considered include:

a) the development of a generic Safety Evaluation Report acceptable to NRC that could be referenced by licensees in their amendment requests. This would aid the NRC staff reviewers to expedite amendments;

b) possible certification of generic LEU fuel designs through rulemaking to minimize potential adjudication in individual license applications;

c) possible relief of amendment fees for commerical reactor facilities regarding this NRC requirement.

In addition, it has been pointed out that some of the affected plants have sufficient HEU fuel onsite to provide refueling needs for many years. The possible policy related impacts of this matter, and the funding problems associated with replacement of LEU fuel will be discussed with key DOE staff.

Liaison with the State Department will be carried out by the Office of International Programs. The Department of Energy will be regularly consulted.

Scheduling: Based on the proposed contract being signed in August, the technical impact assessment should be complete in early November. This is the pacing item in the completion of work. The regulatory impact analysis will be performed in parallel to the extent it can. Soon after completion of the analyses, a Commission briefing is scheduled. Current plans are for a spokesman from NEDHO to take part in the briefing. Following Commission guidance, the staff will prepare a rule for consideration for issuance for comment.

Victor Stello

for William J. Dircks
Executive Director for Operations

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Department of Energy
Washington, D.C. 20585

NOV 7 1983

Mr. Robert B. Minogue
Director
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Minogue:

This is in reference to the Nuclear Regulatory Commission's (NRC) plan to issue a rule on the conversion of NRC licensed research reactors to low enriched uranium (LEU) fuel. In view of the impact this action may have on our university research and training reactors, we would like to make our views and concerns known to the Commission.

We note that the major reason given for converting U.S. research reactors from high enriched uranium fuel (HEU) is to reduce the potential of HEU fuel being exported for use in foreign reactors. The Nuclear Non-Proliferation Act of 1978, however, focuses primarily on nuclear power technology. As you know, we already have in place a strong and effective nuclear materials safeguards program. The strict application of the principles of the Act to the domestic nuclear situation is redundant, particularly where reactors used solely for research and training are concerned. We firmly believe, therefore, that it was not the intent of this legislation to require universities with small training and research reactors or other low flux facilities to discontinue using HEU. Unless there are compelling reasons, these institutions should not be asked to interrupt the operation of their programs or be subjected to the unnecessary economic or technical penalties of conversion.

The Department of Energy (DOE), as I am sure you know, has supported the objectives of the Act in establishing and funding the "Reduced Enrichment for Research and Test Reactors (RERTR) Programs." Currently, fuel fabrication technologies are being developed to meet the requirements of most research reactors now using U.S. supplied HEU. The LEU fuel development program has the following objectives:

1. Ease of fabrication with procedures as similar as possible to the HEU process
2. Minimize impact of enrichment change on reactor operation, in order to reduce potential economic penalties
3. Avoidance of extensive modifications of the safety analysis report
4. Assurance that both experimental capabilities and fuel cycle costs will not be significantly penalized by conversion to LEU fuel

Although most domestic university reactors could technically be converted to the use of LEU, we urge that this proposed rule apply only in those few cases that realistically relate to the objectives of the Act. Most of the low power teaching and research reactors have a "lifetime core" either in place or in storage. In those cases where university reactors are holding HEU in greater than formula quantities, arrangements can be made to store any unirradiated fuel either at the fabricator's facility or at a DOE site. For those university reactors that can convert with minimum impact, such as at the University of Lowell, the Rhode Island Nuclear Science Center and the University of Virginia, we would anticipate using up any HEU fuel elements currently in storage and phasing in LEU elements as the demand for fuel arises.

There are two university reactors (the University of Missouri and MIT reactors), however, where the uranium densities required for high performance operation exceed the highest densities (7.0gU/cc) being developed for LEU fuel. Both of these reactors have technical features that prohibit the use of LEU fuel without experiencing severe penalties in operating capabilities. We would recommend that provisions be made for exempting these two facilities.

In view of the current economic pressures that most universities are experiencing, care should be taken not to add unnecessarily to these burdens. Our ability to meet the training and research needs for the full range of nuclear applications is strongly dependent upon the university community and these nuclear facilities.

We will be pleased to work with you and your staff in developing an acceptable program that meets our national needs and commitments.

Sincerely,

Al Trivelpiece

Alvin W. Trivelpiece
Director, Office of
Energy Research

cc: Harold Denton, Director
Office of Nuclear Reactor Regulation

February 1, 1984

NOTE TO: Chairman Palladino

FROM: W. J. Dircks
Executive Director for Operations

SUBJECT: DRAFT GUIDANCE FOR FEBRUARY 6, 1984 COMMISSION MEETING

Enclosed is draft guidance dealing with the use of HEU at research reactors.

As you requested in your memo of January 18, 1984, staff has prepared draft guidance which would serve as a basis for discussion at the Commission meeting on February 6, 1984.

(Signed) T. A. Rehm

for

William J. Dircks
Executive Director for Operations

Enclosure:
As stated

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MEMORANDUM FOR: William J. Dircks
Executive Director for Operations

FROM: Samuel J. Chilk
Office of the Secretary

SUBJECT: DEVELOPMENT OF PROPOSED RULE ON HEU AT DOMESTIC RESEARCH REACTORS AND INTERIM SECURITY MEASURES

By memorandum dated June 21, 1983, I reported that the Commission agreed that a proposed rule be developed to implement the Commission's policy for reduction of the use of high enriched uranium (HEU) at domestic research reactors. The Chairman also requested that the staff brief the Commission on the matter before extensive effort was expended in developing the proposed rule. The briefing was held on December 19, 1983, and January 27, 1984, and you are requested to proceed expeditiously with development of the proposed rule.

A. Proposed Rule on HEU at Domestic Research Reactors

In addition to the provisions set out in the memorandum of June 21, 1983, the proposed rule should, to the extent feasible, minimize the licensing burden that could result. Consideration should be given to providing in the rule for automatic extension of existing licenses to cover LEU if prescribed conditions are met. Those conditions should assure that present safety margins are not significantly reduced. To this end the staff should act promptly to initiate a generic safety evaluation report setting forth safety envelopes for the plants under consideration, and the rule package should ask for comment on dealing with the limited changes in safety margins in this manner.

The Commission wishes to review two options:

a. A rule requiring the conversion to LEU fuel of all licensed research and training reactors other than those exempted because of a unique purpose. Under this option, reactors that regularly replace burned up fuel would be required to replace such fuel with low enrichment uranium fuel as the HEU fuel is used up, and as the replacement fuel is available. The schedule for such replacements shall be developed with the Director of NRR who will coordinate such actions with DOE. If a suitable replacement fuel is not expected to be available within the overall schedule for the DOE RERTR program, the licensee shall use a replacement fuel at an enrichment that is as low as technically achievable, based on the technology developed by DOE, until such time as improved technology, permitting operation with fuel at enrichment of 20 percent or less, is available. For reactors that do not expect to require the acquisition of new fuel during the term of their license, a schedule shall be developed with the Director of NRR to provide for as prompt conversion to LEU as is reasonable. The schedules for conversion shall take into account such factors as: scheduling of shipping casks, replacement fuel fabrication, financial support, and reactor usage. It is expected that this schedule will be coordinated with DOE.

b. A rule similar to the option developed above, but restricted to those reactors that expect to acquire new fuel during the term of their license should also be developed.

Further, the proposed rule should establish a schedule for conversion of the higher-powered reactors.

On the basis of information presented at the briefing on December 19, 1983, it is anticipated that the National Bureau of Standards reactor and perhaps the Union Carbide reactor should be considered as serving "unique purposes" and be permitted to continue use of HEU.

For the purposes of this rule, "unique purpose" should account for such characteristics as neutron flux levels and energy spectrum specifically designed to facilitate research or irradiations not readily performed elsewhere in the U.S. The Director of NRR should determine whether the reactor has a "unique purpose."

B. Interim Security Measures at Domestic Research Reactors

Staff should also investigate physical protection requirements applicable during the interim preceding the completion of conversion to LEU. Since nearly all nonpower reactors possessing high enriched fuel currently implement the Category II physical protection requirements of 10 CFR 73.67 (a), these should be addressed before the proposed Category I nonpower amendments are made final. Staff should assess the impact and benefit of alternative measures to be added to the Category II requirements to increase the level of protection at these facilities. The alternatives should include the following:

1. Reduce Holdings of Fresh HEU Fuel at Nonpower Reactors
2. Tamper-Proof Detection Systems and Provide Line-Supervision
3. Assure Presence of Two-Persons During Access to Material
4. Improve Communications Capability
5. Provide Access Barriers over the Reactor Core

Staff shall also investigate whether Interim Category I requirements should be amended:

1. To require submittal for NRC review and approval of the specific measures that the licensee would apply to meet the requirements of 10 CFR 73.60; and

2. To require licensees which apply the 100 rem/hour at 3 feet exemption, to meet only Category II requirements, to demonstrate how they determine that radiation levels are above the level stipulated in the exemption; and

3. To require licensees to notify the NRC at least 48 hours before they expect a change in requirement category.

Upon completion of the above efforts, staff should propose a program to the Commission for the implementation of any improvements deemed necessary. Work on the final rule for theft at Category I nonpower reactors (the permanent rule replacement to 10 CFR 73.60) shall be deferred and a schedule for completion of that effort should be included when staff presents its proposals for Category II changes.

Samuel J. Chilk
Office of the Secretary

49 FR 27769

UNITED STATES NUCLEAR REGULATORY COMMISSION

May 22, 1984

RULEMAKING ISSUE
(Notation Vote)

SECY-84-211

For: The Commissioners

From: William J. Dircks
Executive Director for Operations

Subject: PROPOSED RULE FOR LIMITING THE USE OF HIGH-ENRICHED URANIUM (HEU) IN RESEARCH AND TEST REACTORS

Purpose: To respond to the Commission's request for a Notice of Proposed Rulemaking for limiting the use of HEU in non-power reactors.

Category: This paper covers a major policy question.

Issue: What regulatory requirements should be imposed to implement the Commission's policy of encouraging reduction in use of HEU in domestic and foreign research and test reactors.

Discussion: By memorandum from SECY to the EDO dated February 23, 1984 (attached as Enclosure F), the Commission requested the staff to prepare a proposed rule on the use of HEU and a plan and schedule for development of steps to improve security measures at domestic non-power reactors using HEU fuel. In order to avoid possible delay in responding to the request, two papers have been prepared. This paper concerns the proposed rule (Enclosure A). A separate paper addresses improved security measures.

Contact:
William R. Lahs, RES
44-37874

Background:

In August 1982 the Commission issued a Policy Statement on the use of HEU in research reactors. As stated "...NRC has licensing responsibility for domestic use and for export abroad of Special Nuclear Material, including HEU and is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors." The Policy Statement noted that the U.S. research reactor operators have shown little interest in converting to lower enrichment fuel, and that as part of a policy to strongly encourage conversion by foreign operators, the Commission would take steps to encourage similar action by U.S. research reactor operators.

In follow-up, the Commission requested OPE to propose options for encouraging domestic research and test reactors to convert to LEU. OPE reported by memorandum of March 1, 1983, recommending that NRC pursue two options, i.e., with certain exceptions, (1) license no new research reactors for HEU, and (2) require existing licensees, when refueling, to replace spent HEU fuel with LEU fuel. That recommendation was included in a memorandum of June 21, 1983, that asked the staff to prepare a proposed rule on the subject, but suggested that the staff brief the Commission on the matter before extensive efforts were expended in developing the proposed rule.

The EDO's information paper of August 19 (SECY 83-349) outlined the staff's plans for developing the proposed rule, noting that attention would be focused on the class of university-operated research and test reactors. This class represents the largest number (25) of the 31 NRC licensed research reactors that use HEU.* The university reactors are traditionally supported, in part, by DOE. RES let a short-term contract to Rensselear Polytechnic Institute both to identify and classify the affected university reactors and to address the impacts of converting from HEU to LEU. The contractor's report,"Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel" (NUREG/CR-3666), has been furnished to the Commission and, together with other independent bases generated by DOE and NRC, has been used to develop the regulatory impact of the proposed rule. A copy of the contractor's report is available in the Public Document Room.

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*The total of 31 assumes that the General Electric Test Reactor will be licensed for future operations.

Commission meetings on this subject were held December 19, 1983, January 27 and February 6, 1984. At the February 6 meeting, the Commission provided guidance to the staff on the expected content of a proposed rule. A particularly significant point made at that meeting was that the proposed rule should require conversion both by reactors that routinely replace their fuel and by reactors with "life-time cores." Twenty of the 31 licensed non-power reactors have "life-time cores" and, unless required to do so by a rule change, would not need to acquire additional fuel. Those 20 are authorized to possess a total of about 130 Kg U-235. The other 11 are authorized to possess a total of over 200 Kg U-235.

Subsequently, the Commission directed the staff to submit the proposed rule (and the paper on security measures) to the ACRS for review. It is staff's understanding that ACRS will conduct a review and report to the Commission by mid-June. The staff briefing, scheduled by the Commission in May, will not include ACRS input.

Proposed Rule:

The proposed rule contained in Enclosure A is consistent with the Commission guidance provided in SECY's memorandum of February 23, 1984. The proposed rule, if made effective and if Federal funds are provided for costs of converting would lead to conversion of the HEU fuel in nearly all 31 non-power reactors. Target material, special instrumentation or experimental devices using HEU are not included in the conversion requirements of the proposed rule. The schedule for conversion will be determined by the Director, Office of Nuclear Reactor Regulation.

The proposed rule provides for automatic extension of licenses to cover LEU fuel if certain conditions are met. This provision is expected to help avoid the costs in time and manpower that might otherwise be associated with license amendments. An estimate of the number of licensees that will qualify for automatic extension of their license will be developed during the comment period for the proposed rule.

Recommendations: That the Commission:

1. Consider publication of the proposed amendments and authorize publication of Enclosure A in the Federal Register with a 60-day comment period.
2. Certify, in order to satisfy the requirements of the Regulatory Flexibility Act, 5 U.S.C. 605(b), that this rule, if promulgated, will not have a significant economic impact on a substantial number of small entities. This certification is included in the enclosed Federal Register notice.

3. Note:

   a. That the Environmental Assessment shows that the action proposed will not have a significant environmental impact (Enclosure C).

   b. The Regulatory Analysis (Enclosure B) and the Environmental Assessment (Enclosure C) will be placed in the NRC Public Document Room.

   c. That the proposed rule has been submitted to the Office of Management and Budget for review and approval of the information collection requirements.

   d. That the appropriate Congressional Committees will be informed of the Commission's action (Enclosure D).

   e. That a public announcement will be issued (Enclosure E).

   f. That copies of the notice will be distributed by TIDC, ADM to affected licensees and other interested parties.

   g. That the Chief Counsel for Advocacy of the Small Business Administration will be informed of the certification and the reason for it as required by the Regulatory Flexibility Act.

Scheduling: It is recommended that this paper be considered at an open session and that this paper be placed in the Public Document Room on the day of the Commission meeting.

William J. Dircks
Executive Director for Operations

Enclosures:
A - Federal Register Notice
    of Proposed Rulemaking
B - Regulatory Analysis
C - Environmental Assessment
D - Draft Congressional Letter
E - Draft Public Announcement
F - SECY memo to EDO 2/23/84

This paper is tentatively scheduled for discussion and possible vote at an Open Meeting on Thursday, May 31, 1984.

If a vote is not taken at the meeting, Commissioners' comments or consent should be provided directly to the Office of the Secretary ASAP thereafter.

Commission Staff Office comments, if any, should be submitted to the Commissioners NLT Friday, May 25, 1984, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional time for analytical review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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[7590-01]

ENCLOSURE "A"

Federal Register Notice

of Proposed Rulemaking

NUCLEAR REGULATORY COMMISSION
10 CFR Part 50
Limiting the Use of Highly Enriched Uranium
in Domestic Research and Test Reactors

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Commission is considering amending its regulations to limit the use of highly enriched uranium (HEU) fuel in domestic research and test reactors (non-power nuclear reactors). The proposed amendment generally would require that new non-power nuclear reactors use low enriched uranium (LEU) fuel and that existing reactors replace HEU fuel with LEU fuel when available.

The Commission considers that currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public. The proposed rule is intended only to reduce the risk of theft or diversion of HEU fuel used in non-power reactors. The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use.

DATES: Comment period expires (60 days after publication). Comments received after this date will be considered if practical to do so, but only those comments received on or before this date can be assured of consideration.

ADDRESSES: Comments should be submitted in writing to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch. All comments received will be available for public inspection in the Commission's Public Document Room at 1717 H Street, NW., Washington, DC.

FOR FURTHER INFORMATION CONTACT: William R. Lahs, Jr., Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Telephone (301) 443-7874.

SUPPLEMENTARY INFORMATION:

Background

A Commission policy statement published August 24, 1982 (47 FR 37007), explains NRC's interest in reducing the use of high enriched uranium (HEU) in research reactors. This interest stems from NRC's licensing responsibility for both domestic use and for export abroad of HEU and concern about risks of theft or diversion of this material.

The policy statement also describes a continuing program to develop and demonstrate the technology that will facilitate the use of reduced enrichment fuels. The Reduced Enrichment for Research and Test Reactors (RERTR) program was initiated by the Department of Energy (DOE) and is managed by the Argonne National Laboratory (ANL). Its objective is to prove the ability of new low-enriched uranium (LEU) fuels to replace existing HEU fuel without significant changes to existing reactor cores or facilities, or significant decrease in performance characteristics of the reactors.

Detailed information on the RERTR program was presented by Dr. A. Travelli, ANL, at the International Symposium on the Use and Development of Low and Medium Flux Research Reactors, held October 17-19, 1983, at the Massachusetts Institute of Technology. A copy of Dr. Travelli's paper, "RERTR Program Activities Related to the Development and Applications of New LEU Fuels", is available for public inspection in NRC's Public Document Room at 1717 H Street, NW., Washington, DC.

The RERTR program's progress and anticipated continued success over the next five years have encouraged NRC to undertake a rulemaking proceeding which would cause reduction in the use of HEU fuel in domestic research and test reactors. In initiating this proceeding, the Commission recognizes that licensed non-power reactors now using HEU fuel are operated without undue risk to the health and safety of the general public and improved reactor safety is not the objective. The proceeding is intended only to cause replacement of HEU fuel. (Target material, special instrumentation or experimental devices using HEU, are not included.) This reduction is desirable because HEU, in appropriate form and quantity, can be used to make an explosive device. LEU has relatively little value for this purpose.

About 31 NRC licensed reactors could be affected by the proposed amendment. Of these, 25 are owned and operated by universities, 5 are owned by private business entities, and one is owned by an agency of the Federal Government.

One source of information which identifies and classifies the affected university reactors and addresses the range of impacts of converting from HEU to LEU is a contractor's report, "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel," NUREG/CR-3666. The report is available for public inspection and copying for a fee in NRC's Public Document Room at 1717 H Street, NW., Washington, DC. As part of the development of the proposed amendment, Commission briefings, open to the public, were held December 19, 1983, and January 27, 1984. At the briefings, information was presented by the DOE, Department of State, Nuclear Engineering Department Heads Organization (NEDHO), NRC staff and other interested persons.

Information considered to date indicates that conversion of several non-power reactors from HEU fuel to LEU fuel is technically feasible and, if the goals of the RERTR program are successfully achieved over the next five years, will be technically feasible for almost all the remaining reactors. The information also shows that a major consideration to operators is the cost of conversion which hinges on the availability of vendor supplied fuel. NRC shares the licensees' expressed view that conversion costs should largely or entirely be financed by the Federal Government. Historically, the DOE and its predecessor agencies have provided significant support to research and test reactor programs. The availability of Federal support will be a key factor considered in determining the availability of LEU fuel and schedules for conversion.

Under the proposed rule, non-power reactors with certain exceptions would be required to use LEU fuel. Licensees now authorized to use HEU fuel would be required to develop and submit to the NRC's Director of the Office of Nuclear

Reactor Regulation a proposed schedule for conversion to LEU fuel. In preparing the proposed schedule, account will be taken of factors such as the availability of shipping casks, financial support, and reactor usage. Determination that the conversion fuel is available is dependent upon the successful accomplishment of the tasks set out in DOE's RERTR program and the development of commercially available replacement fuel. A final schedule will then be determined by the Director. This schedule will depend upon the availability of LEU fuel readily adapted to use in the licensee's reactor with minimum modifications or adverse impacts on the licensee's program.

A matter of interest to the Commission in requiring conversion and establishing the schedule will be financial considerations. Interested persons are invited to comment on the extent that they believe the economics of conversion should influence Commission actions.

Technically, in its simplest form, conversion from HEU fuel to LEU fuel consists of replacing relatively low density HEU by relatively high density LEU. By using a higher density of uranium in the fuel matrix, the same amount of U-235 can be present in a fuel element without changing the external dimensions of the element or significantly changing the thermal-hydraulic characteristics of the reactor. Under these conditions it is possible that existing technical specifications will remain unchanged and no unreviewed safety question will be involved. NRC is evaluating the reactor performance and safety aspects of conversion and expects to publish a report prior to reaching a determination on issuance of a final rule.

To facilitate conversion safety reviews, the NRC is considering the development of generic envelopes of safety limits for the several types of non-power reactors. An affected licensee would then submit an analysis showing that both the normal operating and postulated accident conditions of the reactor fall within the limits. These safety limits would be used in establishing limiting conditions of operation (such as coolant flow, coolant pressure, reactivity conditions). Current developments by the RERTR program indicate that these limiting conditions of operation with LEU fuel may not differ significantly from limiting conditions of operation now used with HEU fuel; however, a definitive conclusion on this matter, applicable to all the conversion candidates will depend on the continued success of the RERTR program over the next several years. Comments are invited on this approach of using generic envelopes of safety limits and limiting conditions of operation.

In cases where conversion from HEU fuel to LEU fuel would neither conflict with the technical specification incorporated in the license nor involve an unreviewed safety question, the conversion could proceed without amendment of the license. In other cases, a license amendment would be required. In view of the significance of this proposed rule to the national interest, the Commission, when implementing the rule, intends to waive any licensing fees that would normally be assessed for amending licenses issued to production and utilization facilities.

In summary, the Commission recognizes that successful implementation of the proposed rule, while maintaining the nuclear research and training capability which these reactors provide, depends on (1) the continued success of the DOE funded RERTR program, (2) the development of acceptable, and available, replacement fuel, and (3) the extent of financial and operational support provided to affected licensees by the Federal Government through DOE. The Commission also recognizes that the degree of RERTR program success directly impacts the costs attributed to attendant NRC safety reviews. The Commission, therefore, is especially interested in public comments on these aspects of the proposed rule.

National Environmental Policy Act Consideration

The Commission has determined, under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in 10 CFR Part 51, that promulgation of this proposed rule will not have a significant effect on the quality of the human environment and that, therefore, an environmental impact statement is not required. (The environmental assessment and finding of no significant impact on which this determination is based are available for public inspection at the NRC Public Document Room, 1717 H Street, NW., Washington, DC.)

Paperwork Reduction Act Statement

The proposed rule amends information collection requirements that are subject to the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.). This rule has been submitted to the Office of Management and Budget for review and approval of the paperwork requirements.

Regulatory Analysis

The Commission has prepared a regulatory analysis for the proposed amendment. The analysis examines the costs and benefits of the amendment and the decision criteria considered by the Commission. A copy of the regulatory analysis is available for inspection and copying for a fee at the NRC Public Document Room, 1717 H Street, NW., Washington, DC.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, 5. U.S.C. 605(b), the Commission hereby certifies that this proposed regulation will not, if promulgated, have a significant economic impact on a substantial number of small entities. This proposed regulation affects non-power reactor licensees that own and operate nuclear utilization facilities licensed under section 103 and 104 of the Atomic Energy Act of 1954, as amended. These licensees do not fall within the definition of small businesses set forth in section 3 of the Small Business Act, 15 U.S.C. 632, or within the Small Business Size Standards set fort in 13 CFR PART 121.

List of Subjects in 10 CFR Part 50

Antitrust, Classified information, Fire prevention, Incorporation by reference, Intergovernmental relations, Nuclear power plants and reactors, Penalty, Radiation protection, Reactor siting criteria, Reporting requirements.

Under the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and 5 U.S.C. 553, notice is hereby given that adoption of the following amendment to 10 CFR Part 50 is contemplated.

PART 50 - DOMESTIC LICENSING OF PRODUCTION AND UTILIZATION FACILITIES

1. The Authority citation for Part 50 continues to read as follows:

Authority: Secs. 103, 104, 161, 182, 183, 186, 189, 68 Stat. 936, 937, 948, 953, 954, 955, 956, as amended, sec. 234, 83 Stat. 1244, as amended (42 U.S.C. 2133, 2134, 2201, 2232, 2233, 2236, 2239, 2282); secs. 201, 202, 206, 88 Stat. 1242, 1244, 1246, as amended (42 U.S.C. 5841, 5842, 5846), unless otherwise noted.

Section 50.7 also issued under Pub. L. 95-601, sec. 10, 92 Stat. 2952 (42 U.S.C. 5851). Sections 50.57(d), 50.58, 50.91 and 50.92 also issued under Pub. L. 97-415, 96 Stat. 2701, 2073 (42 U.S.C. 2133, 2239). Section 50.78 also issued under sec. 122, 68 Stat. 939 (42 U.S.C. 2152). Sections 50.80-50.81 also issued under sec. 184, 68 Stat. 954, as amended (42 U.S.C. 2234). Sections 50.100-50.102 also issued under sec. 186, 68 Stat. 955 (42 U.S.C. 2236).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), §§50.10(a), (b), and (c), 50.44, 50.46, 50.48, 50.54 and 50.80(a) are issued under sec. 161b, 68 Stat. 948, as amended (42 U.S.C. 2201(b)); §§50.10(b) and (c) and 50.54 are issued under sec. 161i, 68 Stat. 949, as amended (42 U.S.C. 2201(i)); and §§50.55(e), 50.59(b), 50.70, 50.71, 50.72, and 50.78 are issued under sec. 161o, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

2. A new §50.64 is added to read as follows:

§50.64 Limitations on the Use of High Enriched Uranium in Non-power Reactors.

(a) Applicability. The requirements of this section apply to all nuclear non-power reactors licensed under §§50.21(a), 50.21(c), or 50.22 of this part.

(b) Definitions. For purposes of this section:

(1) "High enriched uranium" (HEU) fuel means fuel in which the weight percent of U-235 in the uranium is 20% or greater. Target material, special instrumentation or experimental devices using HEU are not included.

(2) "Low enriched uranium" (LEU) fuel means fuel in which the weight percent of U-235 in the uranium is less than 20%.

(3) "Unique purpose" means that the project or program cannot reasonably be accomplished without the use of HEU fuel, and may include:

(i) A specific experiment or program,

(ii) Reactor physics or reactor development based explicitly on use of HEU fuel,

(iii) Research projects based on the neutron flux levels or spectra only attainable with HEU fuel, or

(iv) A reactor core of special design that could not perform its intended function without using HEU fuel.

(c) Requirements.

(1) The Commission will not issue a construction permit for a new non-power reactor that would use HEU fuel unless the applicant demonstrates that the proposed reactor will have a unique purpose as defined in (b)(3).

(2) Unless the Director of the Office of Nuclear Reactor Regulation has determined, based on a request submitted in accordance with

paragraph (d)(1) of this section, that the reactor has a unique purpose, each licensee currently authorized to possess and use HEU fuel in connection with the operation of a non-power reactor shall:

(i) Acquire no additional HEU fuel if LEU fuel acceptable to the Commission for that reactor is available at the time of the proposed acquisition of the HEU fuel by the licensee; and

(ii) Replace all HEU fuel in the licensee's possession with available LEU fuel acceptable to the Commission in accordance with a schedule determined pursuant to paragraph (d)(2) of this section.

(3) If not required by paragraphs (c)(1) and (2) of this section to use LEU fuel, the applicant or licensee must use HEU fuel of enrichment as close to 20% as is available and acceptable to the Commission.

(d) Implementation.

(1) Any request by a licensee for a determination that a reactor has a unique purpose as defined in paragraph (b)3, should be submitted with supporting documentation to the Director of the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555, by (insert a date 6 months after the effective date).

(2) By (insert a date 12 months after the effective date) each non-power reactor licensee authorized to possess and use HEU fuel shall develop and submit to the Director of the Office of Nuclear Reactor Regulation a proposed schedule for meeting the requirements of paragraphs (c)(2) or (3) of this section. The proposed schedule shall be based upon availability of replacement fuel acceptable to the Commission and consideration of other factors such as the availability of shipping casks, financial support, and reactor usage. A final schedule will then be determined by the Director of the Office of Nuclear Reactor Regulation.

(3) If the replacement of HEU fuel with LEU fuel does not change the technical specifications incorporated in the license or involve an unreviewed safety question as defined in §50.59(a)(2), the licensee shall maintain records and furnish reports as defined in §50.59(b). If replacement of HEU fuel with LEU fuel changes the technical specifications incorporated in the license or involves an unreviewed safety question, the licensee shall file an application for an amendment in accordance with §50.59(c).

Dated at ______________this day of _____________________, 1984

For the Nuclear Regulatory Commission.

____

Samuel J. Chilk,

Secretary of the Commission.

Enclosure B

REGULATORY ANALYSIS
OF
LIMITING THE USE OF HIGH-ENRICHED URANIUM (HEU)
IN NON-POWER REACTORS

REGULATORY ANALYSIS
OF
LIMITING THE USE OF HIGH-ENRICHED-URANIUM (HEU)
IN DOMESTIC NON-POWER REACTORS (10 CFR PART 50)

A. STATEMENT OF PROBLEM

The proposed rule implements a stated Commission policy[1] to limit the use of high-enriched-uranium (HEU) in non-power reactors. This policy stems from concern about the risks of theft or diversion of this material. This regulatory analysis assesses the impacts of implementing the proposed rulemaking action requested by the Commission.[2]

B. OBJECTIVE

The objective of this regulatory action is to define the acceptable program for limiting the use of high-enriched-uranium in domestic non-power reactors.

C. ALTERNATIVES

The program, acceptable to the Commission for limiting the use of HEU fuel in non-power reactors, includes the following summarized features:

(1) Construction permits for new non-power reactors that use HEU fuel will not be issued unless the applicant demonstrates that the proposed reactor has a unique purpose.

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[1] Federal Register notice published August 24, 1982 (47 FR 37007)

[2] Memorandum to W. Dircks from S. Chilk, Development of a Proposed Rule on the Use of HEU and Steps to Improve Security Measures, February 23, 1984.

(2) Each current non-power reactor licensee authorized to possess and use HEU fuel, if unable to demonstrate a unique purpose for the reactor, shall

  (i) Acquire no additional HEU fuel if acceptable LEU fuel for that reactor is available at the time of acquisition of the fuel by the licensee; and

  (ii) Replace all HEU fuel in the licensee's possession with available acceptable LEU fuel on a determined schedule.

(3) For those facilities demonstrating a unique purpose, the applicant or licensee must use HEU fuel of enrichment as close to 20% as practical.

As proposed, a process is provided by which the applicant or licensee can submit alternative courses of action based on defined considerations, which, if determined to meet the intent of the rule, will minimize functional, licensing and monetary impacts. The cost and benefits of the proposed action, assessed in the following section, reflect consideration of this implementation policy.

D. CONSEQUENCE OF PROPOSED ACTION

Costs and Benefits

About 31 NRC licensed non-power reactors (including the General Electric Test Reactor) could be affected by the proposed rule. Of these, 25 are owned and operated by universities, 5 are owned by private business entities, and 1 is owned by an agency of the Federal Government. The HEU fuel for the university reactors is owned by, supplied by and returned to the Federal Government. The privately owned facilities receive HEU from the Federal Government, are charged for its use, and return the expended HEU to the Federal Government. The consequences of the proposed rule include societal costs and benefits, direct costs and benefits, and public and occupational health impacts. The societal cost and benefits are intangible and difficult to assess quantitatively, yet the reduction in theft or diversion risks is the overriding consideration in the decision process. The direct costs and benefits are generally quantifiable if certain programmatic assumptions are made. These costs and benefits are associated with facility conversion to the use of reduced enrichment fuels and with the actions necessary to support the licensing process. Public and occupational health impacts are expected to be minor but are speculative because of their dependence on specific conversion procedures and transportation requirements.

The assumptions which form the basis of this regulatory analysis are as follows:

(1) The technology to replace the HEU fuel in non-power reactors with LEU fuel or, in one or two cases with HEU fuel of reduced enrichment, is or will be available within the next several years.

(2) The above technology will allow HEU to LEU (or reduced enrichment HEU) conversion to take place without any significant decrease in safety margins or requiring major reactor modifications.

(3) Factors such as availability of shipping casks, financial support to the converting facility and changes in overall reactor performance (reactor characteristics, reliability, and operating costs) will not cause significant adverse impacts.

(4) Replacement of HEU fuel will take place as rapidly as acceptable replacement fuel can be delivered.

The reasonableness of assumptions (1), (2) and (3) hinges largely on the presumed ability of the RERTR program to successfully attain its goals over the next several years. Assumption (3) also presumes a substantial level of Federal Government financial and technical support. Assumption (4) presumes the cooperation of fuel element manufacturers in providing commercially available LEU replacement fuel. A variety of opinions on the significance and reasonableness of these assumptions is available in additional published documents.[3]

Societal Costs and Benefits

The major societal benefit of limiting the use of highly-enriched-uranium fuel in research and test reactors is a reduction in the global risks of theft or diversion of this material. Widespread use of HEU fuel, both domestically and internationally, increases the risks of theft or diversion of this material. In comparison with HEU, the use of fuel with lower enrichments reduces theft or diversion risks. As a part of the national effort to allay these concerns, DOE's Reduced Enrichment for Research and Test Reactors (RERTR) program[4] was established to develop and demonstrate the technology that facilitates the use of reduced enrichment fuels in research and test reactors. The proposed rule carries out the Commission's commitment to act expeditiously to review the use of LEU fuels in domestic research and test reactors licensed by the NRC. In so doing, the Commission encourages conversion by foreign operators and establishes a basis for carrying out its responsibilities to make findings that exports of HEU would not be inimical to the common defense and security of the United States. The net result, therefore, responds to the national policy to reduce global risks of HEU theft or diversion.

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[3] Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel, NUREG/CR-3666, November 15, 1983; Testimony Before the Nuclear Regulatory Commission, January 27, 1984; Research Reactor Core Conversion from the Use of Highly Enriched Uranium to the Use of Low Enriched Uranium Fuels Guidebook, IAEA-TECDOC-233, 1980.

[4] RERTR Program Activities Related to The Development and Application of New LEW Fuels, Dr. A. Travelli, October 1983.

Two societal costs can be identified with imposition of the proposed rule. The first is the one-time differential safeguards and radiological risk associated with the HEU to LEU fuel replacement operations, including transportation. The second is the loss-in-capabilities cost brought about by potential decisions to curtail specific reactor operations.

The one-time differential safeguards and radiological risk can be identified with the 20 facilities having "lifetime cores." The proposed HEU to LEU conversion process will require these facilities to undergo a single refueling cycle during which HEU fuel will be removed from the facility. Since similar operations with HEU would otherwise occur only at the end of the facilities' normal life, some additional societal risk would occur because of the early scheduling of these HEU fuel handling and shipping operations. No significant additional societal risk can be identified which can be attributed to the early scheduling of these HEU handling and shipping operations. For those reactors with routine refueling cycles, the proposed rule provides implementation provisions which minimize or eliminate the need for non-routine HEU fuel handling operations although, if the scheduling for these operations is accelerated, some incremental societal risk will also be accelerated.

The second societal cost could be the loss-in-capabilities cost brought about by potential decisions that would curtail specific reactor operations. The implementation provision of the proposed rule attempts to minimize the financial, functional, administrative and licensing costs of the conversion process. For some of the facilities, arguments are made that the conversion process provides expanded opportunities to further the facility's educational goal. However, the current reduced interest in nuclear programs could lead to facility shutdown decisions which could impact on longer term, broader, national goals in research and education. For the facilities above 1-2MW in power, conversion could have an impact on the source of neutrons and gamma radiation necessary for specific research or production processes. Of most concern is the capability to produce short-lived isotopes for medical research and diagnosis which could be affected by temporary or permanent facility shutdowns or competitive market forces. Again, however, the implementation provisions of the rule are intended to provide reasonable opportunity for minimizing any potential losses in facility capabilities and availability.

Direct Costs/Benefits of Conversion

The direct cost/benefits of limiting the use of HEU in research and test reactors can include: (1) fuel replacement costs, (2) transportation costs, (3) any facility modification costs necessary to accommodate fuel changeover, (4) lost revenue costs, (5) administration and licensing costs, and (6) reduced safeguards costs. For the most part, the assessments in this analysis are based either directly or indirectly on information provided in NUREG/CR-3666, which includes an assessment of the implications of LEU conversion for the 25 university reactors which use HEU fuel.[5] The assessment, in turn, relies heavily on information from the LEU demonstration program at the Ford Nuclear Reactor (FNR) at the University of Michigan and a LEU Conversion Survey including all 25 university reactors using HEU fuel.

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[5] NUREG/CR-3666, page 4

Fuel Replacement Costs

The assessment of fuel replacement costs is facilitated by dividing the 31 NRC licensed non-power reactors using HEU into two categories: (1) those 11 which currently have routine refueling cycles and (2) those 20 which do not refuel frequently (designated as having "lifetime cores"). In the first category, the assumption is made that HEU fuel is replaced at the time of a normal refueling by either LEU or reduced enrichment HEU fuel as rapidly as this fuel can be delivered, and unused HEU is returned to DOE for disposal. For the 6 university reactors, assumed to be in this first category it is estimated that about 130 still useable HEU fuel elements (~ 2300 plates) would be scrapped. If the average usage of these elements is assumed to be 50% of normal life, lost fabrication costs are estimated at about $500,000. For the 4 privately owned and the NBS reactors about 170 HEU fuel elements would be scrapped. Under the same assumptions as above, lost fabrication costs are estimated at about $700,000. In general, fabrication charges per core are assumed to be similar for LEU and HEU fuel and changes in fuel use charges, where applicable, are assumed to be small with respect to these fabrication costs. The fabrication cost assumption is especially critical and is dependent on the development of commercially competitive LEU replacement fuel. In addition, fuel cycle times are assumed to be similar for LEU and HEU fueled cores. Therefore, no direct costs, after the initial changeover, are assigned.

For the 20 facilities with "lifetime cores", 16 would require the replacement of between 3000 and 4000 fuel plates in over 300 fuel elements plus replacement of over 400 TRIGA elements. Assuming no change in the facilities' useful life, lost fabrication costs are not discounted and are estimated at about 5 million dollars.

The University of California-Santa Barbara has a uranyl sulfate solution reactor. The present fuel should last to 1995. Conversion to LEU would thus require unloading the reloading fuel solution at a very minor cost. The three remaining reactors contain concentric tube-type fuel elements. Because of the unusual fuel design, lost fabrication and fuel design costs could not be quantitatively assigned. If a supplier for this fuel type is not available, a large change in reactor design may be required to use available fuel.

Transportation Costs

The differential transportation costs inherent to the proposed rule are those associated with the return of the replaced HEU elements to DOE. Variations of this cost between facilities would be expected as a result of the varying shipment distances and the number of shipments required. Physical protection requirements in effect at the time of shipment could also dramatically affect transportation costs. Assuming these costs currently range from $30,000 to $80,000 per facility (entire core),[6] a total transportation cost from $1-$2.5 million dollars is estimated.

Facility Modification Costs

The three previously mentioned concentric tube reactors and the RPI reactor which contains unusual fuel may require modifications whose costs currently cannot be quantified. The only other potential facility modification cost which can be identified, given the previously mentioned conversion scenario assumptions, is associated with upgrading the fuel handling capabilities (shipping cask handling crane) at those facilities with "lifetime cores." Assuming a $25,000 cost[7] at half of the 20 facilities would yield an additional facility modification cost estimated at $250,000 dollars.

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[6] Ibid

Lost Revenue Costs

Lost revenue costs cannot be quantitatively identified. Detrimental impacts, if any, would most likely be limited to high power facilities and their magnitude would be largely influenced by the line which divides facilities with "unique purposes," as defined in paragraph 50.64(b)(3), from those in which conversion causes a penalty in lost revenue costs. Under the regulatory analyses assumptions, a high likelihood of successful development of high density low enriched uranium fuel is presumed which would minimize the potential for lost revenue impacts.

Administration and Licensing Costs

Administration and licensing costs, even under the conversion scenario assumptions, are likely to exhibit significant variations. The major variable involves the degree to which a generic licensing approach can be used to accommodate the conversion processes. If the RERTR program succeeds in attaining its goals over the next several years, the likelihood of successfully applying a generic approach is presumed to increase. For the 25 to 26 low to medium power facilities costs would include program planning and the preparation of information documenting that LEU conversion does not result in a conflict with existing technical specifications or involve an unreviewed safety question. If the generic licensing approach is feasible, these costs would be minimized. In either case, the gathering of core physics and thermal hydraulic information (most likely limited to information needed for potential accident evaluations) would most likely be encompassed by typical training or educational tasks within the capabilities of many of the university nuclear programs. The licensing and administration costs for these facilities are estimated to range from $25,000 (assuming generic licensing) to $75,000 if a case by case review is required. For these facilities over 2MW, administration and licensing costs may be more extensive. For these facilities, assessment of normal operation as well as accidents will be required to document the absence of conflicts with existing technical specifications as well as the non-existence of any unreviewed safety question. For these facilities, licensing costs could range from a total of $50,000 to $75,000 assuming generic licensing to the $250,000 per reactor estimate made in NUREG/CR-3666. Therefore, the total administration and licensing costs of the assumed conversion process is estimated between $1.5 million (with generic licensing) and $3 million dollars.

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[7] Ibid

Reduced Safeguard Costs

For most reactors, conversion from HEU to LEU fuel would permit a facility to employ a lower classification of safeguards requirements. This lower classification could lead to a small savings in safeguards costs based on existing requirements. The savings, however, would be further increased after implementation of additional safeguards measures being pursued by staff in response to the

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[8] Ibid

February 23, 1984 memorandum from the Commission.[9] The financial benefit of this reclassification has not been quantified. In addition to this cost savings, an argument can be made that the educational value of university facilities is enhanced as the requirements imposed by safeguards regulations are removed.

(3) Public and Occupational Health Impacts

Limiting the use of high-enriched-uranium in non-power reactors is not expected to result in any significant public or occupational health impacts. Under the presumed conversion scenario assumptions, the only identifiable public and occupational health impacts would result from defueling and transportation operations involving the displaced HEU fuel.

At the facilities with routine refueling cycles, the changeover to reduced enrichment fuel will cause only a minor increase in the number of fuel shipments which would normally occur over the facilities lifetime. For the "lifetime core" facilities, an estimated 50 shipments would be required to dispose of the HEU fuel.

The limited scope of these operations together with the continued applicability of the transportation and radiation protection standards of 10 CFR 71 and 10 CFR 20 assure that the public and occupational health impacts will be extremely small.

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[9] Memorandum to W. Dircks from S. Chilk, page 4

Impacts on Other Requirements

The proposed rule has significant impacts on DOE programs and, based on the conversion scenario assumptions, a lesser, but still significant impact on NRC. The assumptions on the availability of acceptable fuel to replace existing HEU implies continued funding and success of the RERTR program over at least the next 5 years (the RERTR Program costs (estimated at 4-5 million dollars per year) have not been included in the conversion cost estimates). The proposed rule also implies Federal assistance in providing the replacement fuel and, for facilities presently supported by the Federal Government, financially supporting the supplementary analytical/design/planning activities of the conversion candidates. The magnitude of this Federal assistance is dependent both on the success of the RERTR Program and the extent to which generic licensing can be prudently used in the conversion process.

Requirements imposed on NRC include the staff time necessary to review the licensee's "unique purpose" submittals or conversion schedules, to determine a final acceptable conversion schedule, to determine the extent to which generic or lead facility licensing concepts can be used, and to review the licensee findings regarding conflicts with existing technical specifications and unreviewed safety questions. Early coordination with both the DOE funded programs and the licensees to develop the criteria for submitting acceptable replacement procedures and schedules would minimize the impact on all parties involved in the conversion process.

Constraints

The major constraints that affect the implementation of the proposed rule are availability of acceptable commercially available replacement fuel, availability of shipping casks, financial support, and development of an acceptable LEU fuel cycle for the affected non-power reactors. These constraints have been addressed in the previous section.

E. DECISION RATIONALE

The proposed rule has been prepared in response to the Commission's request of February 23, 1984. The decision to limit the use of HEU fuel in non-power reactors involves a weighing of the societal benefits of reducing global risks of HEU theft or diversion against the conversion costs to the 31 NRC licensees and to the Federal Government.

As indicated in this regulatory analysis, the proposed rule attempts to minimize impacts by providing a flexible process through which the licensee can accomplish the required conversion.

The societal benefit, although intangible, involves reducing the undefined possibility of an event whose costs might be extremely high. The major costs of conversion are the identified financial impact of 9 to 12 million dollars (excluding RERTR Program costs) and the other non-quantifiable costs discussed in the analysis. Most of these costs will be borne by the taxpayers of the United States.

F. IMPLEMENTATION

Implementation, as defined in proposed §50.64(d) requires licensees to submit a proposed schedule for fuel conversion within 12 months of the effective date of the rule. For licensees attempting to demonstrate facilities with unique purpose, a request for determination is required within 6 months of the effective date of the rule.

ENCLOSURE "C"

Environmental Assessment

ENVIRONMENTAL ASSESSMENT AND FINDING OF NO SIGNIFICANT IMPACT For Proposed Amendment to 10 CFR 50 to Limit the Use of High-Enriched Uranium in Non-Power Reactors

The Commission has determined, under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in 10 CFR Part 51, that promulgation of the proposed amendment of 10 CFR Part 50 to limit the use of high-enriched uranium (HEU) fuel in non-power reactors will not have a significant effect on the quality of the human environment and that, therefore, an environmental impact statement is not required. This determination is based on an environmental assessment and finding of no significant impact performed in accordance with the procedures and criteria in Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," as published in the Federal Register, March 12, 1984.

Part 51 is the NRC's regulation for assuring appropriate environmental consideration of licensing and regulatory actions. Generally, under Part 51 any licensing or regulatory action will fall within 1 of 3 classes. The first class of actions consists of those actions which require an environmental impact statement. The criteria for and identification of such actions are given in §51.20. This class of actions includes matters such as issuance of a construction permit or operating license for a nuclear power plant. The third class of actions consists of those actions eligible for categorical exclusion following a Commission declaration that the category of actions does not individually or cumulatively have a significant effect on the human environment. The criteria for and identification of licensing and regulatory actions eligible for categorical exclusion are given in §51.22. Amendments to

Commission regulations which are corrective or of a minor or nonpolicy nature and do not substantially modify existing regulations, fall within this third class of actions.

The second class of licensing and regulatory actions, for purposes of environmental considerations, are those actions which are neither identified in §51.20 as requiring an environmental impact statement nor identified in §51.22 as qualifying for categorical exclusion from preparation of an environmental impact statement or assessment. The criteria for and identification of licensing and regulatory actions requiring environmental assessments are given in §51.21. The proposed amendment of 10 CFR Part 50 to limit the use of HEU fuel satisfies the requirements of §51.21 and accordingly the below assessment has been prepared.

The required contents of an environmental assessment are set out in §51.30 as follows:

§51.30 Environmental assessment.

> (a) An environmental assessment shall identify the proposed action and include:
> (1) A brief discussion of:
> (i) The need for the proposed action:
> (ii) Alternatives as required by section 102(2)(E) of NEPA.
> (iii) The environmental impacts of the proposed action and alternatives as appropriate; and
> (2) A list of agencies and persons consulted, and identification of sources used.

The following comments respond to the specific requirements of §51.30.

The proposed action is to amend Part 50, "Domestic Licensing of Production and Utilization Facilities," of the Commission's regulations to limit the use of high-enriched uranium (HEU) fuel in non-power reactors. As proposed, with certain exceptions, no new non-power reactors will be approved for use of HEU fuel and, also with certain exceptions, all of those non-power reactors now authorized to use HEU fuel will be required to replace that fuel with low-enriched uranium (LEU) fuel. The change to LEU fuel will reduce the risk of theft or diversion of the HEU. This reduction is desirable because HEU, in appropriate form and quantity, can be used to make an explosive device. LEU has relatively little value for making an explosive device.

The proposed amendment of Part 50 directly affects only NRC non-power reactor licensees and applicants for non-power reactor licenses. However, this action with respect to NRC regulated non-power reactors may serve as a model for foreign non-power reactors, thus reducing international traffic in HEU.

Section 102(2)(E) of NEPA provides that agencies of the Federal Government shall - "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." The objective of the proposed amendment is to reduce, preferably to zero, the risk of theft or diversion of HEU. The preferred objective can be achieved by replacement of HEU fuel by LEU fuel. Now or within the next few years, the conversion to LEU fuel will be technologically feasible for nearly all non-power reactors. Until a non-power reactor does convert to LEU fuel, an interim action is increased security measures. This interim action, although valuable over the short term to reduce the risk, does not eliminate the risk of diversion of HEU at non-power reactors as does the proposed action of required conversion to LEU fuel.

The proposed amendment will affect neither the safety of operation nor the routine release of radioactivity from non-power reactors. The amendment will only cause replacement of HEU fuel by LEU fuel and thus reduce the risks of theft or diversion. The exposure of the public to radiation will remain essentially unchanged. Some additional radiation exposures, principally to occupational workers, may occur as a result of converting non-power reactors that have "life-time" cores. The proposed amendment will cause these reactors (about 20) to undergo an additional reactor core removal and transport. These activities will be conducted in accordance with the provisions of 10 CFR Part 20, "Standards for Protection Against Radiation," and 10 CFR Part 71, "Packaging and Transportation of Radioactive Material" and will not cause significant individual or collective radiation doses.

A financial cost is associated with converting the non-power reactors to LEU fuel. The total cost for all the reactors to be converted is estimated to be on the order of 9-12 million dollars. This cost would be spread out over a several year period. Financial support by the Federal Government is expected to cover economic expenditures by the licensees.

During development of the proposed amendment, the Commission consulted with the Department of Energy and Department of State. Commission briefings, open to the public, were held. At the briefings, information was presented by the DOE, Department of State, Nuclear Engineering Department Heads Organization (NEDHO) and other interested persons. A contractor's report, "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel," is on file in the NRC's Public Document Room at 1717 H Street, NW., Washington, DC.

Section 51.31 provides that upon completion of an environmental assessment, the appropriate NRC staff director will determine whether to prepare an environmental impact statement or finding of no significant impact on the proposed action. The Executive Director for Operations has determined that the environmental assessment adequately supports a finding that the proposed amendment will have no significant environmental impact. Accordingly, the Commission has determined not to prepare an environmental impact statement for the proposed action. The proposed amendment will not significantly affect safe operation of the reactors nor the routine release of radioactivity from the reactors. Some additional radiation exposures will be small and spread out over several years. The economic costs of converting non-power reactors to LEU fuel will be borne by the Federal Government and society, as a whole, will be the beneficiary of the reduced risk of theft or diversion of high enriched uranium.

ENCLOSURE "D"

Draft Congressional Letter

DRAFT TRANSMITTAL LETTER TO CONGRESSIONAL COMMITTEES

Dear Mr. Chairman:

Enclosed for your information is a copy of a Notice of Proposed Rulemaking to be published in the Federal Register. The proposed amendment would reduce the use of highly-enriched uranium (HEU) in research reactors and accordingly reduce the risk of theft or diversion of this material.

In August, 1982, the Commission issued a policy statement stating an interest in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors. The proposed amendment would implement that policy with respect to research reactors licensed by the NRC. With certain exceptions, the proposed amendment would require that HEU fuel be replaced by low enriched uranium fuel (LEU).

Thirty-one domestic reactors would be affected by the proposed rule. Twenty-five of these are university reactors used for research and training. One is at the National Bureau of Standards and five are private reactors.

The academic community has showed considerable interest in this rulemaking. Comments have observed that if the universities were required to pay the costs of converting from HEU to LEU fuel, many of the university reactors would have to close. Historically, the Department of Energy has provided significant financial assistance to the university reactors. If the budget permits, DOE is expected to continue this financial support.

The notice of proposed rulemaking allows 60 days for public comment after which time the Commission will further consider the need for a final rule.

Also enclosed is a copy of a public announcement that will be released by the Commission in the next few days.

Robert B. Minogue, Director
Office of Nuclear Regulatory Research

Enclosures:

1. Notice of Proposed Rulemaking
2. Draft Public Announcement

ENCLOSURE "E"

Draft Public Announcement

NRC PROPOSES TO REQUIRE USE OF LOW-ENRICHED URANIUM FUEL IN NON-POWER REACTORS

The Nuclear Regulatory Commission is proposing to amend its regulations to require owners of non-power reactors (research and test) to use low-enriched uranium fuel.

Low-enriched uranium is uranium enriched to less than 20 percent in the fissionable 235 isotope. The Commission believes that the 31 non-power reactors (25 owned by universities, five by private businesses and one by the government) presently licensed to use high-enriched uranium fuel are operated without undue risk to the public health and safety. However, as proposed, the new rule could reduce the risk of theft or diversion of high-enriched uranium, could encourage similar actions by foreign operators of non-power reactors and, thereby, could reduce the amount of high-enriched uranium in international use.

Under the terms of the proposed rule:

--the Commission would not issue a construction permit for a new non-power reactor designed to use high-enriched uranium fuel unless the applicant could demonstrate that it would serve a "unique purpose" under limitations defined in the proposed rule.
--each licensee currently authorized to possess and use high-enriched uranium fuel in a non-power reactor that does not serve a "unique purpose" would be: (a) prohibited from acquiring additional high-enriched uranium fuel in a non-power reactor that does not serve a "unique purpose" if low-enriched fuel, acceptable to the Commission, were available at the time of the proposed acquisition and (b) required to replace all high-enriched fuel with low-enriched fuel on an NRC-approved schedule.

--a few licensees operating non-power reactors for which conversion to use low enriched uranium fuel would not be technically feasible would be required to use high-enriched fuel enriched as close to 20 percent in uranium-235 as possible.

As proposed, the rule also would require, among other things, that:

--a licensee request for a determination that a presently-licensed non-power reactor has an "unique purpose" would have to be submitted within six months of the effective date of the new rule;

--each licensee authorized to possess and use high-enriched uranium fuel would have to submit a proposed conversion schedule to the NRC within 12 months of the effective date of the new rule.

One of the factors that would be considered by the NRC staff in reviewing proposed conversion schedules would be the economics of conversion.and the Commission particularly is interested in public comments on the extent to which this factor should influence agency actions. Other factors which would be considered would be the availability of suitable low-enriched fuel, the availability of shipping casks and reactor usage.

Written comments on the proposed amendment to Part 50 of the NRC's regulations should be received by (date). They should be addressed to the Secretary of the Commission, Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch.

(A list of non-power reactors currently using high-enriched uranium fuel is attached.)

UNIVERSITY-OWNED, NON-POWER REACTORS LICENSED TO USE HIGH-ENRICHED URANIUM FUEL

1. University of Missouri, Columbia
2. Massachusetts Institute of Technology, Cambridge
3. Georgia Institute of Technology, Atlanta
4. Rhode Island Nuclear Science Center, Narragansett
5. University of Michigan, Ann Arbor
6. University of Virginia, (UVAR), Charlottesville
7. University of Lowell, Lowell, Massachusetts
8. University of Missouri, Rolla
9. Ohio State University, Columbus
10. University of Kansas, Lawrence
11. Worcester Polytechnic Institute, Worcester, Massachusetts
12. Purdue University, West Lafayette, Indiana
13. Rensselaer Polytechnic Institute, Troy, New York
14. University of Virginia (Cavalier), Charlottesville
15. Manhattan College, Riverdale, New York
16. Oregon State University, Corvallis
17. Texas A&M University, College Station
18. University of Wisconsin, Madison
19. Washington State University, Pullman
20. University of California, Los Angeles
21. University of Florida, Gainesville
22. University of Washington, Seattle
23. Virginia Polytechnic Institute and State University, Blacksburg
24. Iowa State University, Ames
25. University of California, Santa Barbara

GOVERNMENT-OWNED, NON-POWER REACTORS LICENSED TO USE HIGH ENRICHED URANIUM FUEL

National Bureau of Standards, Gaithersburg, Maryland

INDUSTRY-OWNED, NON-POWER REACTORS LICENSED TO USE HIGH-ENRICHED URANIUM FUEL

1. General Atomic Company, San Diego
2. General Electric Company (GEP-NTR), Pleasanton, California
3. General Electric Company (GETR), Pleasanton, California
4. Union Carbide Corporation, Tuxedo, New York
5. Westinghouse Nuclear Training Center, Zion, Illinois

ENCLOSURE "F"

SECY Memo to EDO 2/23/84

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
SECRETARY

February 23, 1984

MEMORANDUM FOR: William J. Dircks
Executive Director for Operations

FROM: Samuel J. Chilk
Secretary for the Commission

SUBJECT: DEVELOPMENT OF A PROPOSED RULE ON THE USE OF HEU AND STEPS TO IMPROVE SECURITY MEASURES

The Commission was briefed on current physical security measures at domestic nonpower reactors and on the potential for conversion of these reactors from high enriched uranium to low enriched uranium fuel in meetings held on December 19, 1983, January 27 and February 6, 1984. As a result of these briefings the Commission requests that the staff prepare expeditiously (by March 30, 1984) for Commission consideration a proposed rule on the use of HEU, and a plan and schedule for development of steps to improve security measures at domestic nonpower reactors using HEU fuel.

RES

A. Proposed Rule on HEU at Domestic Research Reactors

The proposed rule should contain the following provisions:

1. No new nonpower reactors would be licensed for use of HEU fuel unless the applicant shows the unique purposes of the project cannot be achieved without using HEU fuel.

2. Existing nonpower reactors would be required to convert to LEU fuel if it is technically feasible for them to do so.

    - Reactors that refuel would be required to replace such fuel with low enrichment fuel as the replacement fuel becomes available. The schedule of such replacements would be developed by the Director, NRR, who will coordinate such actions with DOE. If a suitable replacement fuel is not expected to be available within the overall schedule of DOE's RERTR program, the rule should provide for replacement of HEU fuel with fuel of enrichment as close to 20 percent as practical.

    - For reactors that would not otherwise expect to require the acquisition of new fuel during the term of their license, a schedule should be developed by the Director, NRR, to provide for as prompt conversion to LEU as is reasonable.

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- Schedules for conversion should take into account such factors as: scheduling of shipping casks, replacement fuel fabrication, financial support, and reactor usage. These schedules should be coordinated with DOE.

3. Exemptions from this rule would be based on a determination that the particular reactor serves a unique purpose. Unique purpose should account for such characteristics as neutron flux levels and energy spectrum specifically designed to facilitate research on irradiations not performed elsewhere in the U.S. The Director, NRR would determine whether a reactor has a unique purpose. Commissioner Gilinsky would prefer that the Commission itself make this determination.

4. In order to minimize costs to licensees of obtaining permission to use low enriched uranium, consideration will be given to including in the rule provisions which would permit existing licensees automatically to convert their facilities to LEU if prescribed conditions are met. These conditions should assure that present safety margins are not significantly reduced. To this end the staff should act promptly to develop the technical basis needed to support generic findings which would permit conversion to LEU.

5. The rulemaking should request comments on the question of how much the issue of economic feasibility should influence the conversion of facilities to LEU.

6. This rulemaking is based upon Congress funding DOE to provide the appreciably lower enrichment and LEU fuel for university reactors.

NMSS B. Proposed Steps to Improve Physical Protection at Domestic Research Reactors

The proposed steps should consider, for the period preceding the completion of conversion to LEU fuel, alternative strengthened security measures at licensed NPRs, including any available estimates of the benefits and impacts of the following possible improvements:

1. Augmented Minimal Protection for Both Category I and II Facilities

   - Reduce holdings of fresh HEU fuel at nonpower reactors
   - Provide tamper-proof detection systems and line-supervision
   - Assure presence of two-persons during access to material

- Improve communications capability
- Provide access barriers over the reactor core.

2. Additional Protection for Category I Facilities

   - Require submittal for NRC review and approval of the specific measures that the licensee would apply to meet the requirements of 10 CFR §73.60; and
   - Require licensees who, under the 100 rem/hour at 3 feet exemption, meet only Category II requirements to demonstrate how they determine that radiation levels are maintained above the level stipulated in the exemption; and
   - Require licensees to notify the NRC at least 48 hours before they expect a change in requirement category.

3. Transportation

   The staff should recommend options for strengthening present Category II HEU transportation safeguards requirements for consistency with upgraded protection at nonpower reactors.

The staff should report back to the Commission by March 30, 1984 with recommendations on (1) which of the above improvements or others should be implemented, (2) when they should be in place, and (3) the method of implementing them (e.g., license condition, rulemaking). The goal should be assurance that upgrades needed to strengthen security will be put in place expeditiously, but with due consideration given to relevant safety considerations.

Work on the final rule for theft at Category I nonpower reactors (the permanent rule replacement to 10 CFR §73.60) shall be deferred, but should include a reexamination of the technical basis for the present irradiation exemption and whether irradiation provides a sufficiently effective inherent safeguards protection for formula quantities of SNM to justify the significantly lower level of physical protection associated with Category II.

Implementation

In developing the proposed rule and steps (A and B above) the staff should provide answers to the following questions: (1) whether the conversion to LEU fuel can be done strictly by rule, without license amendments, or whether license amendments will be required; (2) if license amendments are required, whether and under what circumstances hearings would need to be held on those amendments; and (3) whether a negative declaration, environmental assessment, or environmental impact statement is required for either the rule or, if required, the license amendments.

cc: H. Plaine
J. Zerbe
C. Kammerer

UNITED STATES NUCLEAR REGULATORY COMMISSION

RULEMAKING ISSUE
(Notation Vote)

May 25, 1984

SECY-84-216

For: The Commissioners

From: William J. Dircks
Executive Director for Operations

Subject: Security Measures at Nonpower Reactors

Purpose: To supply a plan and schedule to increase security measures at nonpower reactors (NPRs) that use high enriched uranium (HEU) fuel.

Category: Major policy issue.

Discussion: This paper replies to the second part (item B) of the Commission's staff requirements memorandum issued by the Secretary on February 23, 1984. That part requested a plan and a schedule for development of steps in increase security measures at NPRs that use HEU fuel. In addition, staff was asked to consider similar improvements for material in transit. A reply to the first part of the requirements memorandum, which requested that staff prepare a proposed rule on conversion of high enriched uranium NPR fuel to low enriched uranium (LEU), is being forwarded separately.

Background

At the December 19, 1983 Commission meeting on the conversion of about 30 nonpower reactors from HEU fuel, a question was raised as to whether the Commission's motivation for seeking conversion was primarily based on international considerations or whether it was also based on domestic safeguards considerations. As a consequence of

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427-4040

that question, in a memorandum dated December 21, 1983 (Enclosure A), the Chairman requested staff's assessment of the adequacy of security at nonpower reactors, and its recommendations for any upgrades deemed necessary. At that time, staff was working on a final security rule for the 13 NPRs possessing five kilograms or more of U-235 in HEU (Category I NPR rule). The Chairman's December 21 memorandum also requested information on the extent to which that pending rule would affect the adequacy of security.

In a memorandum dated January 25, 1984 (Enclosure B), staff informed the Commission that:

a. The security improvements the Commission has pursued during the last several years have represented a reasoned, balanced approach consistent with Section 104 of the Atomic Energy Act. However, staff also believes that as long as high enriched uranium exists at nonpower reactors in significant quantities, some residual risk of malevolent use exists.

b. Of the approximately 30 reactors which possess HEU, most are implementing Category II safeguards requirements because they either possess between 1 and 5 kg of U-235 (Category II quantities) or possess 5 kg or more (Category I quantities) but maintain enough of their fuel irradiated to at least 100 rem/hr at 3 feet to be exempt from Category I requirements.

c. Category II requirements provide for early detection of an external adversary and notification of local law enforcement authorities. Their response does not necessarily have to be timely enough to prevent a theft. The basis for staff's position that these measures provide an adequate degree of security were: (i) theft of multiple Category II quantities would be required to accumulate sufficient material to construct a nuclear explosive device, and (ii) the likelihood of a successful multiple theft was low.

d. Currently available information contains no indication of a specific threat aimed at a domestic nuclear facility. However, recent acts by international terrorists have shown that a significant adversary capability can materialize without sufficient warning from the intelligence community. These recent acts in other countries have also exhibited a significant increase in sophistication, coordination, and willingness to commit violence. Therefore, it may be prudent to consider additional, domestic, security measures to increase the conservatism associated with the protection now provided for Category II quantities.

e. The Category I NPR rule that was in preparation in December, 1983, would affect only one to three of the 30 HEU licensees, since only 13 have Category I quantities and most of these follow Category II requirements because of the 100 rem/hr exemption.

f. The additional Category II security measures being considered would apply only to licensees who possess HEU. (NPRs who converted to LEU would become subject to the less rigorous Category III security requirements.- see Enclosure C).

In two meetings on February 6, 1984, and in the February 23, 1984, staff requirements memorandum, the Commission indicated that staff should proceed expeditiously with steps to strengthen security. The plan for carrying out the Commission's instructions is addressed in the following paragraphs.

Augmented Minimal Protection for Both Category I and II Facilities.

The Commission's February 23 staff requirements memorandum requested recommendations on which of the following improvements, or others, should be implemented:

a. Reduce holdings of fresh HEU fuel at nonpower reactors.

b. Provide tamper-proofed and line-supervised detection systems.

c. Assure presence of two persons during access to material.

d. Improve communications capability with law enforcement organizations.

e. Provide access barriers over the reactor core.

In response to the Commission's direction, Item a provides an expeditious means to increase conservatism. Some licensees possess more fresh fuel than is needed for near term operation of their reactors. Conservatism would be improved if the HEU fuel not needed in the near term is moved to locations where security equivalent to that at facilities processing HEU can be provided. Staff has already commenced discussions with DOE concerning storage of this fuel.

Items b thru e provide increased security capability for: 1) the limited fresh fuel which is essential to efficient reactor operations, 2) fuel in reactor cores, and 3) irradiated fuel in storage. Because each of the approximately 30 HEU NPRs is designed to operate with about 3 kg or more in the core, the proposed improvements would remain in place until the reactors are converted to LEU and all the existing HEU fuel, fresh and irradiated, is shipped offsite. This is estimated to take from 8 to 10 years provided federal funding is made available and no technical problems arise. After conversion, the licensee would be subject to a less rigorous level of security requirements (most likely Category III requirements).

Implementation of items b through e would increase conservatism by contributing to the following capabilities: 1) impeding removal of fuel from reactors having a core in an open pool (item e), 2) protecting against theft by an insider (item c), and 3) upgrading the ability to detect an attempted theft and to alert the LLEA.

The Commission's February 23 staff requirements memorandum also requested recommendations on any other improvements which should be implemented. In response to the Commission's direction, three other improvements have been identified that would contribute to the conservatism in addition to items a through e above. These additional improvements are:

f. Detect both unauthorized penetration through barriers into, as well as unauthorized activities within, the controlled access area.

g. Detect attempts to prevent the assessment of an alarm, for example, by use of a duress alarm by the assessor.

h. Arrange with the local law enforcement agency (LLEA) to supply at least one armed response person when called upon.

Enclosure D contains a discussion of items a through e, the additional measures (items f, g and h), acceptable alternatives where applicable and available, and the limited cost information presently available (more complete cost information will be developed from discussions with the licensees and comments received on the proposed rule).

Additional Protection for Category I Facilities.

The Commission's February 23 staff requirements memorandum requested recommendations on which of the following improvements, or others, should be implemented:

a. Require submittal for NRC review and approval of the specific measures that the licensee would apply to meet the requirements of 10 CFR §73.60;

b. Require licensees who, under the 100 rem/hour at 3 feet exemption, meet only Category II requirements to demonstrate how they determine that radiation levels are maintained above the level stipulated in the exemption; and

c. Require licensees to notify the NRC at least 48 hours before they expect a change in requirement category.

Conservatism would be increased by implementing the following: (1) require a licensee to notify the NRC and submit a letter committing to the additional measures which will be employed to satisfy §73.60 at least 48 hours before that licensee expects no longer to be exempt from §73.60 provisions (i.e., tell NRC inspection and licensing what increased security will be implemented at the facility) and (2) limit the use of the 100 rem/hr at 3 feet exemption criterion (§§73.67(b)(1)(i) and 73.60) to reduce physical security no more than one level (under current regulations this exemption can be used to reduce requirements any number of physical security levels). In addition, staff will review the procedures that licensees use to determine the external dose rate of their fuel when they are claiming an exemption under the 100 rem/hr at 3 feet criterion. Item (1) may not affect any licensees, and would likely affect no more than two. Item (2) would affect two licensees.

Since the development of a final Category I physical protection rule will eventually take place, staff does not recommend requiring plans for meeting 10 CFR 73.60 from all NPRs with Category I quantities of material because these plans would have to be changed when the final Category I requirements are published. It would be unnecessarily burdensome on the licensee to require submission of two different plans in a short period of time.

Transportation

The Commission's February 23 staff requirements memorandum requested staff to recommend options for strengthening present Category II HEU transportation safeguards requirements for consistency with upgraded protection at nonpower reactors. To be consistent, changes in the transportation requirements should lower the likelihood of simultaneous thefts, including simultaneous thefts from a Category II site and a Category II shipment. The following options are set forth for consideration. (A more complete analysis of the options is given in Enclosure E.)

1. Make no change in the physical security requirements.

2. Upgrade transportation physical security requirements by adding upgrades in conjunction with the fixed site security improvements previously outlined.

   The upgrades to the present §73.67(e) in transit requirements for physical protection of Category II HEU would be:

   o require dedicated transports with a driver and an escort,

   o require seals on containers and locks and seals on the cargo compartment, and

   o require in transit communications capable of requesting assistance from local law enforcement agencies (LLEA).

The total approximate impact to licensees (University reactors) for shipments made under option 2 is $57,600 per year for the dedicated transports. Costs for the other provisions are not available at this time.

3. Upgrade the physical security requirements as outlined in option 2 only for shipments of 3 kg to 4.99 kg of HEU.

   Under this option, fixed site Category II facilities would be limited to 2 kg or less of fresh HEU fuel on site unless a special need can be demonstrated (special cases will be handled on a site specific basis). With this limitation, only theft of shipments of 3 kg or more could result in a 5 kg loss if there were a simultaneous theft of fresh HEU fuel stored at any one Category II site. Thus, shipments of 3 kg or more would receive the higher level of protection of option 2. At the same time, for those shipments where the simultaneous thefts would result in less than a composite 5 kg loss, the current level of Category II protection would continue to be provided. Assuming that, for option 3, large shipments would be broken up into more, smaller shipments, the estimated impact of this option would be to increase the number of shipments per year to University reactors (mostly University of Missouri) by 3 to 4 at an approximate total cost of $1,600 per year.

   Option 3 results in minimal cost impact while providing a higher degree of protection against the simultaneous combined theft of more than 5 kg of HEU fresh fuel from a Category II site and a Category II shipment. Upon Commission decision, the staff would pursue this upgrading parallel with the fixed site physical security upgrade.

Method of Implementing the Recommended Improvements

In its February 23 staff requirements memorandum, the Commission requested recommendations on how to accomplish the improvements with the goal of implementing the upgrades on an expedited basis. Alternative methods specifically identified were license conditions and rulemaking. There are three variations on license conditions: voluntary licensee modifications of their security plans, an immediately effective order under 10 CFR 2.204, and a regular order for modification of license under 10 CFR 2.204. The following discussion and recommendation reflects the Commission's expressed desire to proceed expeditiously.

Alternative 1: Voluntary security plan modification. Informal discussions with a small sampling of licensees indicate a willingness to voluntarily modify plans on a site-by-site basis, particularly if a good set of criteria were available. If this action is approved, criteria could be developed in three weeks. With three teams of two headquarters personnel each (1 security and 1 reactor safety), supplemented by one inspector, six to eight site visits and documentation of improvements could be completed every two weeks. Procedural improvements and licensee commitments to make physical changes could be achieved within 11 to 13 weeks at all sites which cooperate. The need for physical changes is very site specific, and thus, will be impossible to predict without the site visits. It should be noted that the voluntary approach could be considered a form of "ratcheting."

PRO - Changes at highest priority sites could be initiated within five weeks.

- Phased implementation of upgrades could be accomplished with the most important sites handled first.
- All site visits and commitments could be completed in 13 weeks.
- Site visits would contribute significantly to identifying cost-effective improvements.

CON - Depends on voluntary cooperation from licensees.

- Possibility of nonuniform application.
- Would require the reassignment of approximately 2.0 SY of effort to unbudgeted tasks.
- Licenses may become inconsistent with the regulations.
- Contrary to agency practice of effecting generic modifications by rulemaking.

Alternative 2: Immediately effective orders under 10 CFR 2.204. This type of order requires a licensee to implement the ordered changes within a time specified in the order. The licensee can request a hearing, but cannot wait for the hearing prior to implementing the ordered changes. This would be the fastest alternative but is not considered to be viable in this situation because legally it can be used only if there is a finding that the public health, safety, or interest requires immediate effectiveness.

Alternative 3: Regular orders issued under 10 CFR 2.204. This type of order provides the licensee with an opportunity to request a hearing prior to implementing the order and can be used in the case being considered. The orders could be prepared and issued in 6-8 weeks, with implementation (excluding physical changes) within a total elapsed time of about 3 months. However, if a hearing is requested, it could add significant time and resource needs.

PRO - Uniform application if a hearing is not held.

- Does not depend on voluntary cooperation.

- Less manpower intensive, if hearings are not requested.

CON - It would be difficult to take into consideration site specific characteristics.

- Several requests for hearings would significantly delay implementation, and place a heavy strain on staff resources.

- Licenses may become inconsistent with the regulations.

- Contrary to agency practice of effecting generic modifications by rulemaking.

Alternative 4: Expedited rulemaking. Enclosure F shows a schedule which would reduce to 47 weeks the normal 2-3 year period required for development of a proposed and final rule. The expedited schedule recognizes that a draft rule for augmented protection for both Category I and II facilities who are currently subject to Category II requirements has already been prepared and circulated for staff review. Revised licensee security plans would be submitted within a month after a final rule is published and approved within 2 to 5 weeks after submittal. This expedited schedule can be accomplished by creating a task force to develop the rule and by the following deviations from normal regulatory process.

1. There will be no review by the Department of State or the CRGR during both the proposed and final rule stages;

2. The Regulatory Analysis will be prepared for the final rule only, will use impact and cost data obtained during the rule's public comment period, and will not be reviewed by the CAG;

3. Acceptance Criteria for license review will not be ready until the final rule development stage;

4. Staff concurrence will be by ELD, IE, NMSS, NRR and RES only; and

5. The OMB clearance package will be prepared and receive staff review at the same time that the Commission considers the proposed rule.

PRO - Uniform application.

- Does not depend on voluntary cooperation.

- Staff review of proposed licensee plans facilitates incorporation of site specific considerations.

- Provides for an expedited rulemaking schedule.

CON - Improvements at highest priority sites would not be implemented for about 53 weeks.

- Would not receive benefit of the full range of review afforded in normal rulemaking.

Implementation Approach

Given the Commission's direction to develop a plan for expeditious implementation, none of the individual implementation alternatives is acceptable. Accordingly, the Commission may want to consider a combined approach. Upon Commission approval, resources would be redirected to form a task force to concurrently develop two rules. The first rule will improve the protection for both Category I and II facilities, subject to Category II requirements, and the transportation of Category II quantities of material. This rulemaking will go through a proposed and final rule stage on an expedited schedule. The second rule will make needed interim additions to the Category I NPR requirements, those applicable when the 100 rem/hr exemption is not being maintained. This rulemaking can go directly to the final rule stage.

Concurrent with the rulemaking effort, resources would be redirected to form a second task force to begin the "voluntary" implementation effort. To make the results of the voluntary program inspectable and enforceable, the licensee would have to document the agreed upon changes in an amendment to its physical protection plan. In the event that a licensee fails to cooperate with the voluntary program, staff would consider issuance of an order. That decision would be based on the priority of the improvements at that site, estimates of time required to complete a hearing, and the stage of development of rulemaking. If an order were issued, then its terms would become the basis for inspection and enforcement of the improvements to be made. Since the rulemaking and voluntary program do not involve a significant impact on the environment, they would be excluded from the need for an environmental impact statement or a negative declaration.

Upon completion of rulemaking and the "voluntary" efforts, a task force would be formed to review and approve the security plans submitted by licensees.

The implementation times, shown in Table 1, represent effecting procedural changes and making commitments to implement physical changes. Where a range of times is listed, highest priority facilities would be completed during the shorter time and lowest priority during the longer time. Orders would be pursued only if needed and only to the extent that they would result in more rapid implementation of the improvements.

TABLE 1

Implementation Program	Implementation Time
"Voluntary" improvements	5 - 13 weeks
Category II/I rule	53 - 56 weeks
Category I rule	30 - 33 weeks

In order to increase the security at nonpower reactors, the Commission could:

1. Direct the following to satisfy its desire for expeditious changes in security:
    a. The improvements (items a through h) for both Category I and Category II facilities which are subject to Category II requirements.
    b. The additional requirements (items 1 and 2) for Category I facilities.
    c. The third option for transportation.
    d. The multi-dimensional expedited implementation approach discussed on pages 9 and 10.
2. Note:
    a. The upgrade discussed in this paper are backfit. In view of the Commission's request for these items to be supplied on an expedited schedule the staff has not subjected them to normally required reviews by the CRGR and the ACRS.
    b. The staff resources to proceed have not been budgeted but must come from redirection of resources. NMSS resources have been made available by suspending work on modification to the Category I rule. Additional NMSS staff redirection will be necessary to proceed further.
    c. This effort results in increased conservatism on a priority basis as desired by the Commission during the several year period for licensees to convert to lower enriched fuel should the Commission desire to proceed with the rule on enrichment conversion.
    d. The staff is not aware of available factual information of a specific threat aimed at a domestic nuclear facility.

e. The Office of Inspection and Enforcement has not concurred on this paper because they do not feel that "consideration has been given to the impact that the proposed alternative methods for implementing the improvements would have on the low level of resources for nonpower reactor safeguards programs available to IE and the Regions."

f. The Office of Nuclear Reactor Regulation has not concurred on this paper for the reasons stated in their memorandum provided as Enclosure G. Basically, the nonconcurrence stems from resource commitments and departure from the standard rulemaking process.

g. This paper has been sent to the ACRS and their review is scheduled for the week of June 11-15, 1984. CRGR reviews are being scheduled.

William J. Dircks
Executive Director
for Operations

Enclosures:
A - Memo of 12/21/83 for the other
Commissioners from Chairman Palladino
B - Memo of 1/25/84 for the Commissioners
from W. Dircks
C - Category III Physical Protection Rqmts.
D - Discussion of Measures to Improve
Category II Rqmts.
E - Analysis of Option for Transportation Rqmts.
F - Accelerated Rulemaking Schedule
G - Memo of 4/18/84 for H. Denton from D. Eisenhut

This paper is tentatively scheduled for discussion at an Open Meeting on Thursday, May 31, 1984. If a Commission decision on how to proceed with the proposed rule is not made at that time, Commissioners' comments or consent should be provided directly to the Office of the Secretary ASAP thereafter.

Commission Staff Office comments, if any, should be submitted to the Commissioners ASAP, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional time for analytical review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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ENCLOSURE A

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

December 21, 1983

MEMORANDUM FOR: Commissioner Gilinsky
Commissioner Roberts
Commissioner Asselstine
Commissioner Bernthal

FROM: Nunzio J. Palladino NJP

SUBJECT: HIGH ENRICHED URANIUM AT RESEARCH REACTORS

After considering the December 19, 1983 meeting on converting from high enriched uranium to low enriched uranium at research reactors, I have the following thoughts.

1. If a security problem is the root motivation for converting, then I think we cannot wait for the many years it could take to make the changes from HEU to LEU. Rather, we must solve any security problem quickly.

2. If instead a perception problem with other nations is the motivating factor, then I think we should proceed judiciously, taking into account the many issues that were discussed at our meeting and that may arise in future meetings.

In the interests of moving expeditiously to closure on Item 1, and as background for our classified meeting on January 27, 1984, I would like the staff's assessment of the adequacy of security at research reactors, along with recommendations for upgrade if deemed necessary. The extent to which the pending upgrade rule would affect the adequacy of security should also be addressed. By copy of this memorandum the staff is requested to provide the Commission with an assessment of security and any recommendations by January 23, 1984.

With respect to Item 2, I suggest that we await the results of our second meeting on January 27 covering the international implications before giving guidance to the staff concerning next steps on a proposed rule or any other course of action.

cc: SECY
EDO
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ENCLOSURE B

NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 25 1984

MEMORANDUM FOR: Chairman Palladino
Commissioner Gilinsky
Commissioner Roberts
Commissioner Asselstine
Commissioner Bernthal

FROM: William J. Dircks, Executive
Director for Operations

SUBJECT: HIGH ENRICHED URANIUM AT NONPOWER REACTORS

The purpose of this memorandum is to respond to Chairman Palladino's December 21, 1983 request to staff to provide background information for the Commission's January 27, 1984 meeting on security at nonpower reactors and the Commission's policy on converting from high enriched to low enriched uranium at nonpower reactors. As the Chairman indicated in his memorandum, conversion to lower enrichments would be a long term solution to the problem of protecting nonpower reactor fuel against theft. In the interim, the Commission must assure that it maintains security requirements which protect the public health and safety with an adequate degree of conservatism. The December 21, 1983 memorandum from the Chairman requested:

1. Staff's assessment of the adequacy of security at research reactors.
2. Recommendations for upgrading security, if deemed necessary.
3. Extent to which the pending upgrade rule would affect the adequacy of security.

Security requirements at nonpower reactors are bounded by Section 104 of the Atomic Energy Act which states, "The Commission is directed to impose only such minimum amount of regulation of the licensee as the Commission finds will permit the Commission to fulfill its obligations under the act to promote the common defense and security and to protect the health and safety of the public and will permit the conduct of widespread and diverse research and development." Staff believes that the security improvements the Commission has pursued during the last several years have represented a reasoned, balanced approach consistent with Section 104 of the Atomic Energy Act. However, staff also believes that as long as high enriched uranium exists at nonpower reactors in significant quantities, some residual risk of malevolent use exists.

CONTACT: R. J. Dube
42-74040

ASSESSMENT OF THE ADEQUACY OF SECURITY

In assessing the adequacy and degree of conservatism of protection at research reactors it is necessary not only to consider the level of security provided but also:

1. The threat.

2. The ability of the intelligence community to give advance warning of a developing event or a planned malevolent act in sufficient time to implement additional countermeasures.

3. The deterrent value of irradiated fuel.

4. The length of time it would take to remove fresh or irradiated fuel from a facility (irradiated fuel would normally take longer).

5. The likelihood that an adversary could successfully process either fresh or irradiated fuel to obtain material which potentially could be used to construct a nuclear explosive device, and the time and resources required (processing of irradiated fuel is significantly more difficult).

6. The ability to find and retrieve nuclear material, if stolen (irradiated fuel would be easier to find).

7. The conservatism built into the 5 formula kilogram goal quantity for U-235 (the presence of fission products would increase the conservatism of this number).

8. The likelihood that an adversary could successfully construct a nuclear explosive device (the presence of fission products would make this more difficult).

Of the factors listed above, safeguards requirements for nonpower reactors include direct consideration only for the level of irradiation of the fuel and the length of time it would take to remove the fuel from a facility. Conservatism in the effectiveness of security requirements results from the fact that staff has no knowledge or information of a specific threat aimed at a domestic commercial nuclear facility (recognizing that staff does not have access to all documents or information within the intelligence community) and current requirements do not take into consideration possible advance warning from the intelligence community. Further, the staff does not rely on any conservatism built into the 5 formula kilogram goal quantity for U-235, nor on any likelihood that an adversary would be incapable of separating weapons useable material without detection from nonpower reactor fuel and successfully constructing a nuclear explosive device.

Security requirements are placed on licensees according to the quantity of material possessed--Category II quantities of fuel (less than 5 formula kilograms) and Category I quantities (5 formula kilograms or more)--with the additional provision that Category I material which has been irradiated to a level of 100 rem/hour at 3 feet is protected according to the security requirements for Category II quantities. This is consistent with IAEA guidelines. The 100 rem/hour radiation level, although not an incapacitating level, is considered to be a deterrent. However, it should be recognized that there is a risk of some dedicated individual(s) ignoring this deterrent and obtaining in a single theft sufficient material to fashion an explosive device.

In providing protection, it is recognized that nonpower reactors will have on hand quantities of unirradiated fuel (currently possession is below Category I quantities) in addition to irradiated fuel of Category I. Protection for the irradiated fuel is provided by licensees by using the 100 rem/hour radiation level. Hence, currently the protection in place is that required for Category II quantities.

Category II Quantities (See Enclosure 1)

Recognizing the 100 rem/hour level, the primary security issue with Category II materials is establishing the appropriate level of security for unirradiated fuel in quantities less than 5 formula kilograms. Current requirements were published in July, 1979, and were designed to provide protection against theft at a level consistent with IAEA guidelines. Security plans submitted in accordance with these rules provide for early detection of an external adversary and notification of local law enforcement authorities for their response. The mechanisms for early detection are not designed to protect against an insider and are site-specific, varying in their degree of sophistication and in their vulnerability to a highly trained external adversary. The security measures in place for Category II quantities are summarized in Enclosure 2. Staff's position has been that these measures have provided an adequate degree of security, considering the additional conservatism resulting from the other factors listed above. Important elements in this conclusion are staff's understanding that theft of multiple Category II quantities would be required to accumulate sufficient material to construct a nuclear explosive device and the likelihood of a successful multiple theft was low.

Coordinated theft attempts occurring simultaneously or within a short period of time possibly could defeat NRC's early detection strategy. In view of recent events overseas which suggest successful conspiracies can be accomplished and in view of the Administration's recent prudent actions of increased protection at certain domestic government facilities, staff believes that it would be prudent to consider additional measures which would increase the conservatism associated with the protection now provided for Category II quantities. The pending upgrade rule would not affect the existing requirements for Category II quantities.

Category I Quantities

All of the 13 licensees that currently possess 5 kilograms or more of U-235 in high enriched uranium are maintaining the material at or above 100 rem/hour at 3 feet: thus they must comply with requirements for Category II quantities of material (§73.67). The primary protection, in addition to that required for Category II, relied upon to protect the Category I quantities is the deterrent effect of the 100 rem/hour level. If a licensee were to possess Category I quantities not meeting the 100 rem/hour exemption criterion, it would be required, under current interim requirements, to meet the provisions of §73.60 as well as those of §73.67. The additional measures required by §73.60, outlined in Enclosure 3, would provide specific measures which give some protection against theft of material by an insider. A particular weakness of these interim requirements is that a licensee is not required to submit a security plan, for licensing review and approval, describing the additional measures it would apply to meet the requirements of §73.60, should the fuel in the core drop below the 100 rem/hour level.

The interim requirements will remain in place until the proposed Category I nonpower reactor physical security rule has been published in final form. The Category I nonpower rule published for public comment in July, 1983 contained requirements for:

1. Enhanced dependability of detection systems, irrespective of the skill of an external adversary.

2. Protection of the fuel from theft and protection of the detection systems from tampering by a conspiracy of insiders.

3. A capability to respond to an alarm in sufficient time to prevent the removal of 5 kilograms of uranium-235 in the form of fuel.

4. Submission of a Category I security plan for licensing review and approval even if a licensee's Category I quantities currently meet the 100 rem/hour exemption.

Most licensees would continue to maintain their fuel at 100 rem/hour and, thus, would continue to meet Category II protection requirements.

As a prudent matter, the staff believes consideration should be given to requiring, as an interim requirement, (1) licensee demonstration of how they will assure that the radiation level, for Category I quantities will not be allowed to drop below 100 rem/hour at 3 feet, or (2) submittal for review and approval the specific measures the licensee would apply to meet the requirements of §73.60 should the licensee possess Category I quantities that do not meet the 100 rem/hour level.

RECOMMENDED SOLUTIONS

Measures that would improve the security posture at nonpower reactors may be divided into two classes: those that can be implemented in the near-term through rule revisions or voluntary actions on the part of licensees--the short-term solution--and the long-term solution, conversion to lower enrichments.

Short-Term Solution

For Category II facilities, based on the preceeding discussions, staff recommends the following alternative requirements be analyzed for improving security:

1. Reduce Holdings of Fresh HEU Fuel at Nonpower Reactors
2. Tamper-Proof Detection Systems and Provide Line-Supervision
3. Assure Presence of Two-Persons During Access to Material
4. Improve Communications Capability
5. Provide Access Barriers over the Reactor Core

For Category I quantities, when protection is provided at the Category II level due to the 100 rem/hour deterrent, as noted above, the staff recommends that, as an additional interim requirement, consideration be given to requiring, (1) licensee demonstration of how they will assure that the radiation level for Category I quantities will not be allowed to drop below 100 rem/hour at 3 feet or (2) submittal for review and approval the specific measures the licensee would apply to meet the requirements of §73.60 should the licensee possess Category I quantities that do not meet the 100 rem/hour level.

These improvements could be accomplished by rulemaking or by voluntary action on the part of licensees. Due to current resource limitations in the Division of Safeguards, should the Commission decide to proceed in this direction, work on the Category I updgrade rule would be suspended. The staff believes this is appropriate prioritization of these efforts.

Long-Term Solution

Given the unacceptable consequences of successful theft and construction of a nuclear explosive device, staff believes that implementation of the Commission's policy statement of August 24, 1982, on conversion of nonpower reactors from high enriched to lower enriched fuels would reduce the residual risks. The greatest benefit would be realized if government funding is pursued to ensure that economic considerations do not limit the extent and deliberate speed of conversion to lower enrichments. Thus, in addition to any international benefit the Commission may ascribe to conversion to lower enrichments, the staff believes conversion would also contribute to protection of the public health and safety domestically.

It should be noted, that due to particular needs, several nonpower reactors may not be able to achieve their purposes with lower enriched fuel. These would be subject to any upgrading of Category II requirements.

(Signed) William J. Dircks

William J. Dircks, Executive
Director for Operations

Enclosure:
As stated

cc: SECY
PE
GC

Enclosure B

Category II Quantities. Prior to 1979, physical security at nonpower reactors (regardless of type and quantity of fuel) was provided only to protect against industrial sabotage. Those security measures provided some indirect protection against theft, mainly against an unorganized unsophisticated adversary. There were no physical security requirements for Category II quantities of special nuclear material at other types of facilities, e.g. at low-enriched uranium fuel fabricators. In February, 1977, staff recommended to the Commission (SECY-77-79) that security for Category II materials be provided at a level consistent with IAEA guidelines in INFCIRC/225. The proposed approach upgraded the level of physical protection at nonpower reactors, in addition to introducing totally new requirements for protecting Category II materials at other facilities. The Commission approved the general approach of the staff in June, 1977 (SECY-77-79B).

A proposed rule was forwarded to the Commission in March, 1978 (SECY-78-142), and approved for publication in May, 1978. After review of public comments, a final rule was forwarded to the Commission in January, 1979 (SECY-79-38). Staff's recommended final rule was generally consistent with INFCIRC/225 and included the following requirements:

1. Detect and assess unauthorized access to or activities within a controlled access area containing the special nuclear material;

2. Detect and assess unauthorized removal of special nuclear material;

3. Assure proper placement and transfer of custody of special nuclear material; and

4. Respond to indications of an unauthorized removal of special nuclear material and then notify the appropriate response forces of its removal in order to facilitate its recovery.

On June 21, 1979, the Commission, by a vote of 5-0, approved publication of the final rule subject to the following modifications:

1. Provide early detection and assessment of unauthorized access or activities by an external adversary within the controlled access area containing special nuclear material.

2. Provide early detection of removal of special nuclear material by an external adversary from a controlled access area.

Although voting in favor of the amendments (as revised), Commissioner Gilinsky would have preferred that the modifications to the wording of the requirements include the word "promptly" in lieu of "early," and would have deleted the phrase "by an external adversary."

Category I Quantities. Prior to 1979, Category I quantities of non-power reactor fuel—were exempt from security requirements to protect against theft if the fuel were irradiated to at least 100 rem/hour at three feet. For exempt fuel, the only protection against theft was that indirectly provided by the security systems in place to protect against sabotage. For non-exempt fuel, theft protection was provided by some of the security provisions (§73.60) which applied to fuel cycle facilities if the fuel was irradiated, but at less than 100 rem/hour, and to all of security provisions (§73.50 and §73.60) if the fuel was unirradiated.

In November, 1979, the Commission approved the publication of a final Physical Protection Upgrade rule for fuel cycle facilities which was directed at protection against theft of formula quantities of special nuclear material. Initially, staff had anticipated that this upgrade rule would apply to non-power reactor fuel not irradiated to at least 100 rem/hour at three feet rather than just to fresh fuel. During the public comment period on the proposed upgrade rule, concern was expressed as to whether the physical protection requirements actually were needed at Category I non-power reactor facilities, given the unique type and form of the fuel. In addition, comments focused on the impact that the Upgrade Rule would have on nonpower reactors.

The Commission decided not to require nonpower reactors to meet the requirements of the upgrade rule. As an interim measure, non-power reactors were required to meet the theft protection measures provided by the regulations covering Category II quantities of special nuclear material. Those non-power reactor facilities possessing Category I quantities not meeting the 100 rem/hour exemption criterion were required also to meet the provisions of §73.60. The additional measures required by §73.60, outlined in Enclosure 3, are designed to give some protection against theft of material by an insider. A particular weakness of these interim requirements is that licensees are not required to submit security plans describing the additional measures they would implement to meet the requirements of §73.60 for NRC licensing approval.

When the Commission approved the interim requirements for Category I quantities at nonpower reactors, it directed staff to develop final requirements which would provide protection against theft comparable to the Physical Protection Upgrade Rule, considering the unique type and form of the fuel. A proposed rule to this end was published in September, 1981. In response to extensive public comments, a revised proposed rule was forwarded to the Commission in November, 1982. The Commission approved the proposed rule subject to several staff follow-on actions recommended by OPE. However:

Chairman Palladino would have preferred that the following change:

> The statement that a licensee will now be allowed to average its irradiated fuel in meeting the 100 rem/hour exemption so long as no fuel unit drops below 50 rem/hour at 3 feet should be explicitly shown in the rule as well as in the supplementary information.

Commissioner Gilinsky disapproved the rule and provided the following comments:

> "I approve of including protection against insider theft of nuclear material. I also believe some mention should be made of the possible LEU conversion requirements being considered by the Commission. However, I continue to disagree with most of the provisions in this proposed rule.
>
> 1) The 100 rem/hour is a meaningless number without technical justification. It is useless as a deterrent to any serious terrorist. I continue to advocate a 2,000 rem/hour threshold.
>
> 2) Local law enforcement capabilities and their response times vary from adequate to negligible, and the notification device would have to be protected against any insider or outsider attempt to disarm it. I think the cost may well be greater than that of an on-site guard force which most universities already employ.
>
> 3) The 90-day 'phase-in' period is just another way of lowering the 100 rem/hour level even further.
>
> 4) The proposed rule discourages conversion to LEU fuel by making it easier and cheaper to use HEU fuel.
>
> To summarize, I disapprove this proposed rule. But if it is put out for comment, I would follow OPE's recommendations and include mention of them in the Supplementary Information section."

The final rule for Category I quantities not irradiated to 100 rem/hour would differ from the interim requirements in the following major areas:

1. Enhanced dependability of detection systems, irrespective of the skill of an external adversary.

2. Protection of the fuel from theft and protection of the detection systems from tampering by a conspiracy of insiders.

3. A capability to respond to an alarm in sufficient time to prevent the removal of 5 kilograms of uranium-235 in the form of fuel.

4. Submission of a Category I security plan for licensing review and approval even if a licensee's Category I quantities currently meet the 100 rem/hour exemption.

CURRENT REQUIREMENTS FOR
CATEGORY II* (10 CFR 73.67(d))

1. Store and use material only in a lighted controlled access area (CAA).
2. Monitor the CAA with an intrusion alarm (door switches acceptable) or procedures.
3. Conduct screening (student credentials acceptable) prior to granting unescorted access to the material.
4. Limit CAA access to authorized persons or escorted visitors.
5. Use a badging system and limit access to the controlled access area to persons who require such access in their duties.
6. Provide at least one around-the-clock unarmed watchman to respond to security incidents or emergencies.
7. Provide a communication capability (telephone acceptable) between the watchman and a response force (police acceptable).
8. Search on a random basis vehicles and packages leaving the CAA (visitors only).
9. Establish response procedures.

Note that protection is provided only against an external adversary.

---

*Less than 5 formula kilograms of high enriched uranium and all fuel irradiated to 100 rem/hour at nonpower reactors.

INTERIM

CURRENT REQUIREMENTS

FOR CATEGORY I QUANTITIES BELOW IRRADIATED 100 REM/HOUR

(10 CFR 73.60)

Implement Category II requirements and, in addition,

1. Store and use material in a material access area (MAA) where only necessary activities occur.
2. Enclose the material access area within a protected area to which access is controlled.
3. Store material in a vault or vault type room.
4. Search packages entering the MAA for items to facilitate a theft.
5. Limit MAA access to only necessary persons.
6. Observe persons while they are in the MAA.
7. Search packages, people, and vehicles leaving the MAA for SSNM.
8. Periodically test alarms.

ENCLOSURE C

Physical Protection Requirements for Category III Quantities of Special Nuclear Material (73.67(f)) at Fixed Sites

(1) Store or use special nuclear material only in an area which is demarcated and to which access is controlled (controlled access area),

(2) Monitor the controlled access area to detect unauthorized penetrations or activities,

(3) Have someone available to respond to all unauthorized penetrations into, or activities within, the controlled access area, and

(4) Have response procedures for thefts and threats of theft of special nuclear material.

ENCLOSURE D

MEASURES FOR IMPROVING SECURITY AT NPR LICENSEES POSSESSING HEU AND SUBJECT TO CATEGORY II REQUIREMENTS

The measures listed below are the security improvements to be made by NPR licensees who possess HEU material and who are subject to Category II physical protection requirements. After a statement of each measure, there is a discussion of it, a statement of the general objective, a presentation of alternatives where possible, and to the extent available, a discussion of any cost or impact estimates. The first five measures are those included in the SECY's memo of February 23, 1984.

1. Reduce holdings of fresh HEU fuel.

   Under this measure the licensee would reduce its fresh HEU fuel holdings as low as reasonably necessary to maintain a normal operating schedule. Licensees would normally be allowed to have more than 2 kg only for a short period of time following receipt of a fresh fuel shipment. Lower holdings will substantially reduce the likelihood that a malevolent group could accumulate a significant quantity of fresh HEU through simultaneous thefts at multiple facilities. The current cost of a shipment of fuel is estimated at $400 and it is expected that DOE would agree to accept and store the fuel for the licensee.

2. Provide tamper-indicating detection systems and line-supervision.

   Under this measure licensees would put tamper-alarms on their intrusion detection systems and on the lines carrying the detection signal to an alarm station. This measure will provide an early indication that someone is attempting to neutralize the detection system, which may be the initial step in a theft attempt. This early warning will give more time to make a response which can prevent a successful theft. Many but not all of the licensees already have supervised signal lines.

3. Assure presence of two-persons during access to material.

This measure has a general objective of not allowing a single insider to have unrestricted access to material without some means of detecting his attempted theft of material. Alternative means of satisfying this objective are: a) a two-person rule for material access, b) motion alarms, that cannot be locally deactivated, covering accessible material, c) double locks and separate key control on storage vaults, and d) radiation alarms, that can't be defeated locally, placed over irradiated fuel. Since most NPRs have several graduate students or other workers available, it should not be costly to satisfy a 2-person rule when direct access to material is necessary. Cost estimates for the other measures are not yet available.

4. Establish improved communications capability with the local law enforcement agency.

This measure applies to cases where supervised signal lines are not already tied into the local law enforcement agency. In particular, where a local campus dispatcher must call the police for help, alternative means are a supervised phone line to the police or a redundant method (e.g., radio) of calling the police for help. This will protect against someone cutting the phone line to the police where the dispatcher would not know it or would not have an alternate method to call for help. The cost of this measure would vary by locale; however, one preliminary cost estimate for a back-up radio is $600.

5. Provide access barriers over the reactor core.

This measure would consist of a gate or other cover over the reactor core or pool to impede an attempt to remove the fuel elements. With proper implementation, the barrier could be effective against outsiders as well as a single insider adversary. One licensee has already installed such a barrier and has estimated its cost at $10,000 to $12,000. This may not be a representative estimate for other facilities because of possible variation in the materials to be used, the size of the pool to be covered, the possible incorporation of useful design features that may already exist, and the fact that this one licensee had some specially difficult design considerations. As a result of the possible high cost-associated with a core barrier, alternative means of impeding the removal of fuel will also be considered. Some of these alternatives are: a) locking fuel handling tools where a specially designed tool is needed that is difficult to duplicate, b) locking a crane that is needed to remove a core cover, c) controlling access to special tools used to lock the fuel elements into the core grid plate, and d) reliance on design features already in place such as enclosed tanks or concrete plugs over the core.

In addition to the measures identified in the SECY's memo, the following measures will also be subject to implementation in the voluntary program and rulemaking.

6. Detect both unauthorized entry into, and activities within, the controlled access area.

The current Category II rule only requires that unauthorized entry or activities be detected. Under this measure the licensee should be able to detect both such events. This will provide a defense in depth and give the opportunity to detect a theft attempt as early as possible. This will provide a good chance that a response can be initiated which will stop the theft. In a small room a licensee may be able to use a single motion detector that will sense entry into the room as well as activities in the room. In a large room a licensee could use door and window alarms for entry detection along with a motion detector over the fuel to sense an attempt to access the fuel.

7. Detect attempts to prevent an assessment of an alarm.

Some licensees may have a procedure where they send an unarmed watchman to assess an alarm before deciding whether to call the police for an armed response. The licensee must be able to determine if an adversary attempts to prevent the assessor from calling the police or notifying the dispatcher that the police are needed. This measure is not necessary if an armed police officer or equivalent (see item 8) makes the assessment. Alternative methods are: a) a remote CCTV monitor, b) a check-in time limit for the assessor after which the police are automatically called, or c) the assessor carries a radio that has a duress button.

8. Arrange with the local law enforcement agency (LLEA) to supply at least one armed response person when called upon.

The LLEA could be the police, or campus guards as long as they have powers of arrest, are armed, and have authority to use armed force. The response time of the LLEA should be short enough to have a chance of interrupting a theft given the expected detection time of the system and the time needed to make an assessment, if any. The cost of making such arrangements is expected to be minimal.

ENCLOSURE E

Analysis of Options for Transportation of Category II Quantities of Material

Option 1. Make no change in the physical security requirements.

This option is based on the fact that multiple thefts of more than 5 kg of HEU in transit are precluded under present regulations since no more than 4.99 kg of HEU is permitted to be on the road at any one time. Shipment schedules are controlled and approved at NRC headquarters. This option, which has the least cost impact of the three, does not, however, prevent the multiple theft of Category II quantities of HEU if one took place at a fixed site and, at the same time, another took place during a shipment.

Option 2. Upgrade transportation physical security requirements by adding measures in conjunction with the fixed site security improvements.

The upgrades to the present §73.67(e) in transit requirements for phsyical protection of Category II HEU are:

- require dedicated transports with a driver and an escort
- require seals on containers and locks and seals on the cargo compartment
- require in transit communications capable of requesting assistance from local law enforcement agencies (LLEA).

A preliminary analysis indicates that these additional requirements would cost about 10 times the currently required signature service. A typical trip costs approximately $300 to $400 for signature service and $3,000 to $4,000 for dedicated truck with driver and escort, improved communications, and tamper-proofing. A survey of 1983 Category II shipments discloses that there were approximately 33. Exclusive-use vehicles were used in 17 of these shipments, all of which were export shipments to Japan and import shipments from Canada. Commercial carriers with signature service were used for the remaining shipments. The exclusive-use vehicle shipments normally included a driver and escort, sometimes a radiotelephone in the cab, and locked and sealed cargo compartment.

The total approximate impact to licensees (University reactors) if the 16 commercial shipments were to be made under proposed option 2 requirements would be $57,600 per year. Added to this would be some incremental costs for escorts and radios to the dedicated truck shipments that do not already use this additional security.

Option 3. Upgrade the physical security requirements outlined in option 2 only for shipments of 3 kg to 4.99 kg of HEU.

If this option were approved, fixed site Category II facilities would be limited to 2 kg or less of fresh HEU fuel on site unless a special need is shown. With this limitation, only shipments of 3 kg or more would result in a 5 kg loss if there were a simultaneous theft of an HEU shipment and fresh HEU fuel stored at a Category II site. These shipments would receive the higher level option 2 protection. At the same time, shipments where the simultaneous thefts would result in a total loss of less than 5 kg, the current level of Category II protection would be provided. For option 3, it is expected that where possible a licensee would break its large shipments into smaller shipments of less than 3 kg of HEU each. The estimated impact of this option would be to increase the number of shipments per year to University reactors (mostly University of Missouri) by 3 to 4 at an approximate cost of $1,600 per year. Also, for export/import shipments there may be some additional cost for escorts and radios.

ENCLOSURE F

Accelerated Rulemaking Schedule for Improved Security at NPRs

	Estimated Time to Complete*
Prepare Draft Rule and Obtain Staff Comments	Completed for Category II rule (3 weeks)
ACRS Review and Prepare Commission Paper and Federal Register Notice	8 weeks
Revise Rule and Related Documents	3 weeks
Obtain ADM Review and Revise	1 week
Staff Concurrence	1 week
Proposed Rule to Commission	2 weeks
Commission Review of Proposed Rule (currently prepare and staff OMB Clearance Package)	4 weeks
Publish Proposed Rule	2 weeks
Public Comment Period	4 weeks
Revise Rule Package and License Acceptance Criteria and Prepare Regulatory Analysis	3 weeks
ACRS Review	8 weeks
Revise Rule	2 weeks
Staff Concurrence on Final Rule	1 week
Final Rule to the Commission	2 weeks
Commission Review	4 weeks
Publish Final Rule	2 weeks
Licensees Submit Plans	4 weeks
Plan Approval	2-5 weeks

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*This schedule will start when approved by the Commission.

ENCLOSURE G

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 18 1984

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Darrell G. Eisenhut, Director
Division of Licensing

SUBJECT: COMMISSION PAPER ON IMPROVED PHYSICAL SECURITY AT NON-POWER REACTORS

A February 23, 1984 memo from Chilk to Dircks directed the staff to prepare a proposed rule on the use of HEU, and a plan to improve security measures at non-power reactors using HEU fuel until such time as they can convert to LEU fuel. RES has prepared a proposed rule addressing the use of HEU, which we have concurred in. A Commission briefing is scheduled for April 27. NMSS also prepared a proposed rule to implement improved security measures, which we concurred in several weeks ago. However, in the interim, they revised their approach completely in a proposed Commission paper delivered to us in the evening on April 16 with requested concurrence by 3 PM April 17. The paper is enclosed.

The proposed NMSS approach includes a combination of activities using task forces composed of NMSS, NRR, IE, RES, ELD, ADM and regional staff. One task force would concurrently develop two rules on an expedited rulemaking schedule of 30 weeks, which would exclude ACRS and CRGR review and use several other shortcuts. One rule would augment security at facilities subject to Category II requirements and the second at facilities subject to Category I requirements. Simultaneously, a second task force consisting of three teams would visit all 31 HEU reactor sites over a period of about 5 weeks, seeking voluntary security plan modification by the licensees. The staff would consider issuing 2.204-type orders to licensees who failed to cooperate in the voluntary effort. A third task force would review and approve the revised security plans submitted by the licensees. A Commission briefing on the NMSS paper which presents this proposed approach is scheduled for May 2.

We cannot recommend NRR concurrence in the NMSS proposal for a number of reasons which we discussed with Bob Burnett on April 17. He understands our reservations but says that this paper reflects John Davis' interpretation of what the Commission wants. Our recommended non-concurrence is based on the following reasons:

1) The approach is not responsive to the Chilk memo of February 23, 1984 which directed the staff to consider alternative measures, including available estimates of the benefits and impacts of five specified improvements. (A copy of the February 23, 1984 Chilk memo is included as the last enclosure to the proposed Commission paper).

2) The proposal prescribes very severe actions but has not identified any real problem which warrants such actions.

3) The paper presents four implementation alternatives, none of which is "ideal," and then recommends an approach which combines three of these four "non-ideal" alternatives.

4) Implementation of the proposed plan would require substantial staff resources which we cannot support. We estimate that NRR would have to commit about six senior-level staff for at least 6-9 months.

5) The proposed schedules are unrealistically short.

6) The "voluntary" aspects of the plan appear to have serious potential backfit implications.

In summary, we do not agree philosophically with the NMSS proposed approach, nor do we have the resources to support it. We recommend instead that the staff utilize the standard rulemaking process, which was originally proposed by NMSS and in which we previously concurred, to achieve the desired improvement of security measures at non-power reactors using HEU.

We are available to discuss this matter with you at your convenience.

Darrell G. Eisenhut, Director
Division of Licensing

Enclosure:
As stated

POLICY ISSUE

(Information)

May 30, 1984

SECY-84-220

For: The Commissioners

From: William J. Dircks
Executive Director for Operations

Subject: RESEARCH REACTOR FUEL CONVERSION DEVELOPMENTS AND RELATED ISSUES

Purpose: To inform the Commission of (1) recent developments in the Reduced Enrichment in Research and Test Reactor (RERTR) program which may affect current reactor LEU fuel conversion schedules and (2) a recent meeting with European officials on European research reactor fuel requirements.

RERTR Budget: Under current schedules, the DOE/Argonne RERTR program projects that the bulk of the testing and evaluation requirements for proving the proposed new 20% enriched LEU silicide reactor fuels would be completed by 1987.* Assuming resolution of funding and licensing issues, this schedule would enable initial conversion of candidate U.S. and foreign research reactors to LEU fuel usage by 1988. However, this tentative conversion schedule is heavily contingent upon continuation of adequate DOE funding support for the RERTR test and evaluation programs.

The staff has learned recently that the House Committee on Science and Technology has proposed a FY 1985 funding level for the RERTR program of \$4.932 million. Argonne officials have informally advised the staff that this amount would cause a \$700K shortage, which would preclude the procurement of the LEU fuel for the full-core demonstration and will force a probable one-year delay in completing necessary test and evaluation programs. This delay would extend eventual

Contact: Marvin R. Peterson
Office of International Programs
492-4599

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* Approximately 6-8 of the 31 NRC licensed reactors would be likely candidates for utilizing these silicide fuels.

Discussion: (Continued)

achievement of the program's objectives into the 1990's. The staff is monitoring these developments closely and is also attempting to obtain a more official DOE assessment of the impact of the proposed FY 85 RERTR budget.*

Meeting With European Officials:

As a related matter, on May 14 the staff attended a meeting between U.S. and European officials to discuss European research and test reactor fuel requirements. The European delegation was headed by Juergen Jaspert, Principal Administrator, EURATOM Supply Agency. It was disclosed at the meeting that activities to convert European reactors to LEU fuel were progressing adequately. However, interim HEU fuel exports would be necessary for the next few years until the new LEU fuels were available.

Horst Hassell from NUKEM, the West German fuel fabrication company, noted that the obligation to study conversion to LEU fuel also applies to the U.S. and that, in particular, DOE's research reactors, except for the Oak Ridge Research Reactor (ORR), continued to be conspicuously absent from any participation in reactor fuel conversion studies and possible identification as candidates for conversion. While the European side did not explicitly threaten to reduce cooperation in conversion activities if efforts to convert DOE's reactors were not more forthcoming, it was clear that any failure by the U.S. to cooperate fully in the conversion effort would eventually have a significant impact on the Europeans' approach to the entire matter. Mr. Jaspert voiced concern over unfair

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* As this paper was being dispatched, NRC received a copy of a letter dated May 22, 1984 (Appendix A) from DOE (Laughon) to State (Malone) which confirms that the current proposed budget will probably cause delays in the RERTR program and suggests the possibility of supplementary budget support from other agencies (perhaps including NRC).

Discussion: (Continued)

practices if European reactor operators, in competition with U.S. operators, are placed in an unequal cost position through forced conversions when the U.S. operators enjoy the advantages of non-conversion. The Europeans also expressed serious concerns regarding the still unresolved issue of DOE's policy on the return of spent LEU research reactor fuel to the U.S. for reprocessing or storage. Resolution of this issue is critical to the long-range spent fuel disposition plans of European research reactor operators. As noted by the official from the Petten research center in the Netherlands, LEU fuel cycle costs are expected to exceed HEU fuel cycle costs by approximately 25% and any increase in DOE spent fuel disposition costs may widen this cost differential. The Euratom delegation stated that at least four European reactors are candidates for immediate conversion from HEU to LEU but are prevented from doing so by the lack of a U.S. decision on the return and reprocessing of spent LEU fuels.

As a final matter, Mr. Jaspert also noted that it would be necessary to obtain peaceful end-use assurances from the U.S. Government regarding any future spent LEU research reactor fuel returned to the U.S. from Europe. This new requirement was necessitated by the fact that significant quantities of plutonium would be contained in LEU spent fuel and European officials were not willing to permit the possible use of such produced plutonium in U.S. military programs.

In summary, the staff noted an increased sensitivity on the part of the Europeans regarding the reciprocal obligations on all parties to explore seriously reactor fuel conversion possibilities in all civil research and test reactors. It should be noted, however, that the State Department's position is that U.S. domestic reactor conversion efforts will have only a "marginal" impact on foreign conversion programs.

William J. Dircks
Executive Director for Operations

Appendix:
A. Ltr from KLaughon, DOE to JMalone, DOS, dtd. 5/22/84

DISTRIBUTION:
Commissioners
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ACRS
SECY

APPENDIX A

Department of Energy
Washington, D.C. 20545

RECEIVED
USNRC

'84 MAY 25 A7:33

OFFICE OF
INTERNATIONAL
PROGRAMS

MAY 22 1984

Mr. James J. Malone, Assistant Secretary
for Oceans and International Environmental
and Scientific Affairs
U.S. Department of State
Washington, DC 20520

Dear Mr. Malone:

This is in response to your letter of May 4, 1984, to Assistant Secretary Brewer regarding the level of funding proposed for the Reduced Enrichment for Research and Test Rectors (RERTR) Program in FY 1985. As you are aware, the Presidential request level of $4.8 million was defined by the Arms Control and Disarmament Agency (ACDA) budget submission and, based on congressional actions to date, it appears that funds for the RERTR Program will be included in the Department of Energy's (DOE) Nuclear Energy (NE) budget as has been the case in previous years.

Federal budgets for FY 1985 are very tight as you know, and funding priorities have been carefully prepared for the DOE programs. Within the current DOE-NE budget for FY 1985, planned support for the RERTR Program will very likely be limited to the funding level appropriated by Congress. As you may know, $4.93 million is presently included in the proposed House Energy and Water Development Appropriations Bill for FY 1985. We are coordinating with other offices of DOE but are not optimistic that these efforts will produce the supplemental support needed to initiate the planned full-core demonstration in the Oak Ridge Research Reactor (ORR) in FY 1985.

DOE would welcome any supplemental funding that the Department of State (DOS), ACDA, or other Federal agencies can make available to the RERTR Program. As currently structured, the program contains tasks to evaluate highly enriched uranium export requests, as well as efforts to implement the RERTR Program results. These tasks are important but only peripherially related to the principal DOE RERTR mission of fuels technology development and demonstration. Accordingly, DOS, ACDA, or the Nuclear Regulatory Commission (NRC) funding might be used for these activities thereby freeing existing funds for ORR fuel procurement.

We would be pleased to discuss this matter further if you so desire.

Sincerely,

KO Laughon

Kermit O. Laughon, Director
Office of Spent Fuel Management
and Reprocessing Systems
Office of Nuclear Energy

cc:
Kenneth L. Adelman, Director, ACDA
✓James R. Shea, Director, Office of International Programs, NRC

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
SECRETARY

June 28, 1984 R E V I S E D

MEMORANDUM FOR: William J. Dircks, Executive Director
for Operations
Carlton Kammerer, Director, OCA
Joseph J. Fouchard, Director, OPA

FROM: Samuel J. Chilk, Secretary

SUBJECT: SECY-84-211 - PROPOSED RULE FOR LIMITING THE USE OF HIGH-ENRICHED URANIUM (HEU) IN RESEARCH AND TEST REACTORS

This is to advise you that the Commission (with all agreeing) has approved the proposed rule for limiting the use of HEU in research test reactors, subject to the following:

1. The proposed rule should be modified as indicated on the attached pages; and

2. Items 4 and 5 of the attached memorandum of June 1, 1984 from S. Trubatch to D. Garner, et al should be addressed during the public comment period.

The proposed rule should be revised as indicated and returned for signature and publication in the Federal Register.
(EDO/RES) (SECY SUSPENSE: 6/29/84)

You should advise the appropriate Congressional Committees, issue a public announcement, and send copies to all of the affected licensees and other interested parties.
(EDO/RES/OCA/OPA) (SECY SUSPENSE: 7/13/84)

Attachments:
As Stated

cc: Chairman Palladino
Commissioner Gilinsky
Commissioner Roberts
Commissioner Asselstine
Commissioner Bernthal
OGC
OPE

NUCLEAR REGULATORY COMMISSION
10 CFR Part 50
Limiting the Use of Highly Enriched Uranium
in Domestic Research and Test Reactors

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Commission is considering amending its regulations to limit the use of highly enriched uranium (HEU) fuel in domestic research and test reactors (non-power nuclear reactors). The proposed amendment generally would require that new non-power nuclear reactors use low enriched uranium (LEU) fuel and that existing reactors replace HEU fuel with LEU fuel when available.

The Commission considers that currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public. The proposed rule is intended ~~only~~ to reduce the risk of theft or diversion of HEU fuel used in non-power reactors and the consequences to public health, safety and the environmen from suc theft o diversion. The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use.

DATES: Comment period expires (60 days after publication). Comments received after this date will be considered if practical to do so, but only those comments received on or before this date can be assured of consideration.

ADDRESSES: Comments should be submitted in writing to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch. All comments received will be available for public inspection in the Commission's Public Document Room at 1717 H Street, NW., Washington, DC.

FOR FURTHER INFORMATION CONTACT: William R. Lahs, Jr., Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Telephone (301) 443-7874.

SUPPLEMENTARY INFORMATION:

Background

~~A Commission policy statement published August 24, 1982 (47 FR 37007), explains NRC's interest in reducing the use of high enriched uranium (HEU) in research reactors. This interest stems from NRC's licensing responsibility for both domestic use and for export abroad of HEU and concern about risks of theft or diversion of this material.~~

Insert

The policy statement also describes a continuing program to develop and demonstrate the technology that will facilitate the use of reduced enrichment fuels. The Reduced Enrichment for Research and Test Reactors (RERTR) program was initiated by the Department of Energy (DOE) and is managed by the Argonne National Laboratory (ANL). Its objective is to prove the ability of new low-enriched uranium (LEU) fuels to replace existing HEU fuel without significant changes to existing reactor cores or facilities, or significant decrease in performance characteristics of the reactors.

Detailed information on the RERTR program was presented by Dr. A. Travelli, ANL, at the International Symposium on the Use and Development of Low and Medium Flux Research Reactors, held October 17-19, 1983, at the Massachusetts Institute of Technology. A copy of Dr. Travelli's paper, "RERTR Program Activities Related to the Development and Applications of New LEU Fuels", is available for public inspection in NRC's Public Document Room at 1717 H Street, NW., Washington, DC.

The RERTR program's progress and anticipated continued success over the next five years have encouraged NRC to undertake a rulemaking proceeding which would cause reduction in the use of HEU fuel in domestic research and test reactors. ~~In initiating this proceeding, the Commission recognizes that licensed non-power reactors now using HEU fuel are operated without undue risk to the health and safety of the general public and improved reactor safety is not the objective. The proceeding is intended only to cause replacement of HEU~~

INSERT

On August 17, 1982, the Commission issued a Policy Statement on the use of HEU in research reactors. The Policy Statement indicated that NRC has licensing responsibility for domestic use and for export abroad of Special Nuclear Material, including HEU, and is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors. The Policy Statement also noted that as part of a policy to encourage conversion by foreign operators, the Commission would take steps to encourage similar action by U.S. research reactors operators.

Public Commission meetings on this subject were held December 19, 1983, January 27 and February 6, 1984. As discussed at the meetings, the Commission believes that the 31 nonpower reactors (25 owned by universities, five by private businesses and one by the Government) presently licensed to use HEU fuel are operated without undue risk to the public health and safety. The proceeding is intended only to cause replacement of HEU fuel. (Target material, special instrumentation or experimental devices using HEU, are not included.) This reduction is desirable because

HEU, in appropriate form and quantity, can be used to make an explosive device which can have severe adverse consequences on public health, safety and the environment. LEU has relatively little value for this purpose. The Commission believes that a new rule could reduce the risk of theft or diversion of HEU, could encourage similar actions by foreign operators of nonpower reactors, and, thereby, could reduce the amount of HEU in international use.

One source of information which identifies and classifies the affected university reactors and addresses the range of impacts of converting from HEU to LEU is a contractor's report, "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel," NUREG/CR-3666. The report is available for public inspection and copying for a fee in NRC's Public Document Room at 1717 H Street, NW., Washington, DC. As part of the development of the proposed amendment, Commission briefings, open to the public, were held December 19, 1983, and January 27, 1984. At the briefings, information was presented by the DOE, Department of State, Nuclear Engineering Department Heads Organization (NEDHO), NRC staff and other interested persons.

Information considered to date indicates that conversion of several non-power reactors from HEU fuel to LEU fuel is technically feasible and, if the goals of the RERTR program are successfully achieved over the next five years, will be technically feasible for almost all the remaining reactors. The information also shows that a major consideration to operators is the cost of conversion which hinges on the availability of vendor supplied fuel. NRC shares the licensees' expressed view that conversion costs should largely or entirely be financed by the Federal Government. Historically, the DOE and its predecessor agencies have provided significant support to research and test reactor programs. The availability of Federal support will be a key factor considered in determining the availability of LEU fuel and schedules for conversion.

unless there is a demonstration that the

Under the proposed rule, non-power reactors ~~with certain exceptions~~ would be required to use LEU fuel. Licensees now authorized to use HEU fuel would be required to develop and submit to the NRC's Director of the Office of Nuclear

facility's unique purpose cannot
be accomplished without the use
of HEU.

Reactor Regulation a proposed schedule for conversion to LEU fuel. In preparing the proposed schedule, account will be taken of factors such as the availability of shipping casks, financial support, and reactor usage. Determination that the conversion fuel is available is dependent upon the successful accomplishment of the tasks set out in DOE's RERTR program and the development of commercially available replacement fuel. A final schedule will then be determined by the Director. This schedule will depend upon the availability of LEU fuel readily adapted to use in the licensee's reactor with minimum modifications or adverse impacts on the licensee's program.

A matter of interest to the Commission in requiring conversion and establishing the schedule will be financial considerations. Interested persons are invited to comment on the extent that they believe the economics of conversion should influence Commission actions.

Technically, in its simplest form, conversion from HEU fuel to LEU fuel consists of replacing relatively low density HEU by relatively high density LEU. By using a higher density of uranium in the fuel matrix, it is expected that the same amount of U-235 can be present in a fuel element without changing the external dimensions of the element or significantly changing the thermal-hydraulic characteristics of the reactor. Under these conditions it is possible that existing technical specifications will remain unchanged and no unreviewed safety question will be involved. NRC is evaluating the reactor performance and safety aspects of conversion and expects to publish a report prior to reaching a determination on issuance of a final rule.

To facilitate conversion safety reviews, the NRC is considering the development of generic envelopes of safety limits for the several types of non-power reactors. An affected licensee would then submit an analysis showing that both the normal operating and postulated accident conditions of the reactor fall within the limits. These safety limits would be used in establishing limiting conditions of operation (such as coolant flow, coolant pressure, reactivity conditions). Current developments by the RERTR program indicate that these limiting conditions of operation with LEU fuel may not differ significantly from limiting conditions of operation now used with HEU fuel; however, a definitive conclusion on this matter, applicable to all the conversion candidates will depend on the continued success of the RERTR program over the next several years. Comments are invited on this approach of using generic envelopes of safety limits and limiting conditions of operation.

Any economic analysis should include estimates of the aversion of risk to the public health, safety, and the environment.

In cases where conversion from HEU fuel to LEU fuel would neither conflict with the technical specification incorporated in the license nor involve an unreviewed safety question, the conversion could proceed without amendment of the license. In other cases, a license amendment would be required. In view of the significance of this proposed rule to the national interest, the Commission, when implementing the rule, intends to waive any licensing fees that would normally be assessed for amending licenses issued to production and utilization facilities. Interested persons are invited to comment on the possibility that a license amendment will not be required or that an amendment would not present a significant hazards consideration.

In summary, the Commission recognizes that successful implementation of the proposed rule, while maintaining the nuclear research and training capability which these reactors provide, depends on (1) the continued success of the DOE funded RERTR program, (2) the development of acceptable, and available, replacement fuel, and (3) the extent of financial and operational support provided to affected licensees by the Federal Government through DOE. The Commission also recognizes that the degree of RERTR program success directly impacts the costs attributed to attendant NRC safety reviews. The Commission, therefore, is especially interested in public comments on these aspects of the proposed rule.

National Environmental Policy Act Consideration

The Commission has determined, under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in 10 CFR Part 51, that promulgation of this proposed rule will not have a significant effect on the quality of the human environment and that, therefore, an environmental impact statement is not required. (The environmental assessment and finding of no significant impact on which this determination is based are available for public inspection at the NRC Public Document Room, 1717 H Street, NW., Washington, DC.)

Paperwork Reduction Act Statement

The proposed rule amends information collection requirements that are subject to the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.). This

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

June 1, 1984

MEMORANDUM FOR: D. Garner
R. Goldsmith
M. Lopez-Otin
J. Austin
L. Stoloff

FROM: Sheldon L. Trubatch

SUBJECT: PROPOSED RULE FOR LIMITING THE USE OF HIGH-ENRICHED URANIUM (HEU) IN RESEARCH AND TEST REACTORS - SECY-84-211

I have the following comments on the proposed rule:

1. The proposed rule is intended not only to reduce the risk of theft or diversion of HEU fuel used in non-power reactors but also to reduce the risk of adverse consequences from such theft or diversion. Accordingly, while improved reactor safety is not an objective, improvements in adequate assurance of public health and safety and protection of the environment are objectives. These additional objectives should be recognized in the Statement of Consideration accompanying the proposed rule, and commentors on the rule should be explicitly directed to consider in any economic analysis of conversion such additional assurances to public health safety and the environment. These objectives may also provide a basis for Commission funding of any conversion from HEU to LEU. Thus, I would make the following additions to the Statement of Consideration:

   a. page 1, second full paragraph, second sentence-

      (i) delete the word "only"
      (ii) add to the end of that sentence

   - and the consequences to public health, safety and the environmental from such theft or diversion.

   b. page 3, paragraph ending on top of the page, sentence beginning "This reduction ...", add to the end of that sentence-

> which can have severe adverse consequences on public health, safety and the environment.

c. page 4, first full paragraph, add to the end of that paragraph-

> Any economic analysis should include estimates of the aversion of risk to the public health, safety and the environment.

2. The proposed legal theory for avoiding hearings on conversions from HEU to LEU is sufficiently uncertain to direct commentors attention to that theory. Thus, I would add the following sentence to the end of the first full paragraph on page 5:

   > Interested persons are invited to comment on the possibility that a license amendment will not be required or that an amendment would not present a significant hazards consideration.

3. Proposed 10 CFR 50.64(c) would establish exceptions from the requirement to use LEU if the reactor operation can demonstrate a "unique purpose" requiring the use of HEU. To achieve the aims of the proposed rule, such an exemption should be coupled with a requirement for enhanced physical security over what would be required at that facility using LEU. Accordingly, I would add the following to proposed 10 CFR 50.64(c):

   > 10 CFR 60.54(c)(4). For any facility which the Director, Nuclear Reactor Regulation has determined requires the use of HEU fuel for a unique purpose, the physical security at that facility shall be demonstrated to provide a level of protection to the public health, safety and the environment as would have been provided had the facility operated with LEU fuel.

4. The Regulatory Analysis fails to consider the adverse consequences to public health, safety and the environment which would be averted by reducing the probability of theft or diversion. Because these addition of these considerations would only strengthen the case for the proposed rule, publication of the proposed rule should not delayed pending upgrade of that analysis.

5. While the environmental assessment appears correct, it is poorly organized. Accordingly, during the comment period, the assessment should be rewritten to clearly

identify and compare alternatives - retain status quo, promulgate proposed rule, leave EEU in place but upgrade security over facility life.

The discussion of environmental impacts should also be modified to explicitly include the reduction in possible adverse consequences to public health, safety and the environment which would be realized by reducing the threat of theft or diversion. Finally, some quantitative estimate of occupational exposures should be added to support the finding that such exposures would be insignificant.

Proposed Rules

Federal Register
Vol. 49, No. 131
Friday, July 6, 1984

This section of the FEDERAL REGISTER contains notices to the public of the proposed issuance of rules and regulations. The purpose of these notices is to give interested persons an opportunity to participate in the rule making prior to the adoption of the final rules.

DEPARTMENT OF AGRICULTURE

Agricultural Marketing Service

7 CFR Ch. X

[Docket Nos. AO-160-A62-RO2, etc.]

Milk in Middle Atlantic and Certain Other Marketing Areas; Rescheduling of Hearing on Proposed Amendments to Tentative Marketing Agreements and Orders

7 CFR part	Marketing area	AO Nos.
1004	Middle Atlantic	AO-160-A62-RO2.
1001	New England	AO-14-A60.
1002	New York-New Jersey	AO-71-A74-RO1.
1006	Upper Florida	AO-356-A21.
1007	Georgia	AO-366-A23.
1011	Tennessee Valley	AO-251-A26.
1012	Tampa Bay	AO-347-A24.
1013	Southeastern Florida	AO-286-A31.
1030	Chicago Regional	AO-361-A21.
1032	Southern Illinois	AO-313-A32.
1033	Ohio Valley	AO-166-A53.
1036	Eastern Ohio-Western Pennsylvania	AO-179-A48.
1040	Southern Michigan	AO-225-A36
1044	Michigan Upper Peninsula	AO-299-A23
1046	Louisville-Lexington-Evansville	AO-123-A52
1049	Indiana	AO-319-A33
1050	Central Illinois	AO-355-A22
1062	St. Louis-Ozarks	AO-10-A56.
1064	Greater Kansas City	AO-23-A55.
1065	Nebraska-Western Iowa	AO-86-A42.
1068	Upper Midwest	AO-178-A38.
1075	Black Hills	AO-248-A18
1076	Eastern South Dakota	AO-260-A26.
1079	Iowa	AO-295-A35
1093	Alabama-West Florida	AO-386-A2.
1094	New Orleans-Mississippi	AO-103-A43
1096	Greater Louisiana	AO-257-A31.
1097	Memphis	AO-219-A38.
1098	Nashville	AO-184-A46.
1099	Paducah	AO-183-A36.
1102	Fort Smith	AO-237-A22.
1106	Southwest Plains	AO-210-A44.
1108	Central Arkansas	AO-243-A36
1120	Lubbock-Plainview	AO-328-A25
1124	Oregon-Washington	AO-368-A13
1125	Puget Sound-Inland	AO-226-A30
1126	Texas	AO-231-A52
1131	Central Arizona	AO-271-A25.
1132	Texas Panhandle	AO-262-A35.
1134	Western Colorado	AO-301-A18
1135	Southwestern Idaho-Eastern Oregon.	AO-380-A4.
1136	Great Basin	AO-309-A25.
1137	Eastern Colorado	AO-326-A22
1138	Rio Grande Valley	AO-335-A30
1139	Lake Mead	AO-374-A9.

AGENCY: Agricultural Marketing Service, USDA.

ACTION: Rescheduling of public hearing on proposed rulemaking.

SUMMARY: The hearing on proposed amendments to 45 Federal milk marketing orders, originally scheduled to begin July 11, 1984, has been rescheduled to begin July 25, 1984.

DATE: The rescheduled hearing will convene at 9:00 a.m., local time, on July 25, 1984.

ADDRESS: The rescheduled hearing will be held at the Olde Colony Inn, 625 First Street, Alexandria, Virginia 22314, (703) 548-6300.

FOR FURTHER INFORMATION CONTACT: Richard A. Glandt, Marketing Specialist, Dairy Division, Agricultural Marketing Service, U.S. Department of Agriculture, Washington, D.C. 20250, (202) 447-4829.

SUPPLEMENTARY INFORMATION: This administrative action is governed by the provisions of sections 556 and 557 of Title 5 of the United States Code and, therefore, is excluded from the requirements of Executive Order 12291.

A notice was issued on June 22, 1984 (49 FR 26289), giving notice of a public hearing to be held at the Ramada Hotel Old Town, 901 N. Fairfax Street, Alexandria, Virginia, beginning at 9:00 a.m., local time, on July 11, 1984, with respect to proposed amendments to the tentative marketing agreements and to the orders regulating the handling of milk in the aforesaid marketing areas.

Notice is hereby given, pursuant to the rules of practice applicable to such proceedings (7 CFR Part 900), that the said hearing is rescheduled to be held at the Olde Colony Inn, 625 First Street, Alexandria, Virginia 22314, (703) 548-6300, beginning at 9:00 a.m., local time, on July 25, 1984.

Prior documents in this proceeding:

Notice of Hearing: Issued June 22, 1984; published June 27, 1984 (49 FR 26239).

List of Subjects in 7 CFR Chapter X

Milk marketing orders, Milk, Dairy products.

(Secs. 1-19, 48 Stat. 31, as amended, 7 U.S.C. 601-674)

Signed at Washington, D.C. on July 3, 1984.

William T. Manley,

Deputy Administrator, Marketing Program Operations.

[FR Doc. 84-18082 Filed 7-5-84; 8:45 am]

BILLING CODE 3410-02-M

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule.

SUMMARY: The Commission is considering amending its regulations to limit the use of highly enriched uranium (HEU) fuel in domestic research and test reactors (non-power nuclear reactors). The proposed amendment generally would require that new non-power nuclear reactors use low enriched uranium (LEU) fuel and that existing reactors replace HEU fuel with LEU fuel when available.

The Commission considers that currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public. The proposed rule is intended to reduce the risk of theft or diversion of HEU fuel used in non-power reactors and the consequences to public health, safety and the environment from such theft or diversion. The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use.

DATE: Comment period expires September 4, 1984. Comments received after this date will be considered if practical to do so, but only those comments received on or before this date can be assured of consideration.

ADDRESSES: Comments should be submitted in writing to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch. All comments received will be available for public inspection in the Commission's Public Document Room at 1717 H Street, NW, Washington, DC.

FOR FURTHER INFORMATION CONTACT: William R. Lahs, Jr., Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Telephone (301) 443-7874.

SUPPLEMENTARY INFORMATION:

Background

On August 17, 1982, The Commission issued a Policy Statement on the use of HEU in research reactors. The Policy Statement indicated that NRC has licensing responsibility for domestic use for export abroad of Special Nuclear Material, including HEU, and is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors. The Policy Statement also noted that as part of a policy to encourage conversion by foreign operators, the Commission would take steps to encourage similar action by U.S. research reactors operators.

Public Commission meetings on this subject were held December 19, 1983, January 27 and February 6, 1984. As discussed at the meetings, the Commission believes that the 31 non-power reactors (25 owned by universities, five by private businesses and one by the Government) presently licensed to use HEU fuel are operated without undue risk to the public health and safety. The proceeding is intended only to cause replacement of HEU fuel. (Target material, special instrumentation or experimental devices using HEU, are not included.) This reduction is desirable because HEU, in appropriate form and quantity, can be used to make an explosive device which can have severe adverse consequences on public health, safety and the environment. LEU has relatively little value for this purpose. The Commission believes that a new rule could reduce the risk of theft or diversion of HEU, could encourage similar actions by foreign operators of non-power reactors, and thereby, could reduce the amount of HEU in international use.

The Policy Statement also describes a continuing program to develop and demonstrate the technology that will facilitate the use of reduced enrichment fuels. The Reduced Enrichment for Research and Test Reactors (RERTR) program was initiated by the Department of Energy (DOE) and is managed by the Argonne National Laboratory (ANL). Its objective is to prove the ability of new low-enriched uranium (LEU) fuels to replace existing HEU fuel without significant changes to existing reactor cores or facilities, or significant decrease in performance characteristics of the reactors. The RERTR program's progress and anticipated continued success over the next five years have encouraged NRC to undertake a rulemaking proceeding which would cause reduction in the use of HEU fuel in domestic research and test reactors.

Detailed information on the RERTR program was presented by Dr. A Travelli, ANL, at the International Symposium on the Use and Development of Low and Medium Flux Research Reactors, held October 17–19, 1983, at the Massachusetts Institute of Technology. A copy of Dr. Travelli's paper, "RERTR Program Activities Related to the Development and Applications of New LEU Fuels", is available for public inspection in NRC's Public Document Room at 1717 H Street, NW., Washington, DC.

One source of information which identifies and classifies the affected university reactors and addresses the range of impacts of converting from HEU to LEU is a contractor's report, "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel," NUREG/CR-3666. The report is available for public inspection and copying for a fee in NRC's Public Document Room at 1717 H Street, NW., Washington, DC. As part of the development of the proposed amendment, Commission briefings, open to the public, were held December 19, 1983, and January 27, 1984. At the briefings, information was presented by the DOE, Department of State, Nuclear Engineering Department Heads Organization (NEDHO), NRC staff and other interested persons.

Information considered to date indicates that conversion of several non-power reactors from HEU fuel to LEU fuel is technically feasible and, if the goals of the RERTR program are successfully achieved over the next five years, will be technically feasible for almost all the remaining reactors. The information also shows that a major consideration to operators is the cost of conversion which hinges on the availability of vendor supplied fuel. NRC shares the licensees' expressed view that conversion costs should largely or entire be financed by the Federal Government. Historically, the DOE and its predecessor agencies have provided significant support to research and test reactor programs. The availability of Federal support will be a key factor considered in determining the availability of LEU fuel and schedules for conversion.

Under the proposed rule, non-power reactors woud be required to use LEU fuel unless there is a demonstration that the facility's unique purpose cannot be accomplished without the use of HEU. Licensees now authorized to use HEU fuel would be required to develop and submit to the NRC's Director of the Office of Nuclear Reactor Regulation a proposed schedule for converson to LEU fuel. In preparing the proposed schedule, account will be taken of factors such as the availability of shipping casks, financial support, and reactor usage. Determination that the conversion fuel is available is dependent upon the successful accomplishment of the tasks set out in DOE's RERTR program and the development of commercially available replacement fuel. A final schedule will then be determined by the Director. This schedule will depend upon the availability of LEU fuel readily adapted to use in the licensee's reactor with minimum modifications or adverse impacts on the licensee's program.

A matter of interest to the Commission in requiring conversion and establishing the schedule will be financial considerations. Interested persons are invited to comment on the extent that they believe the economics of conversion should influence Commission actions. Any economic analysis should include estimates of the aversion of risk to the public health, safety and the environment.

Technically, in its simplest form, conversion from HEU fuel to LEU fuel consists of replacing relatively low density HEU by relatively high density LEU. By using a higher density of uranium in the fuel matrix, it is expected that the same amount of U-235 can be present in a fuel element without changing the external dimensions of the element or significantly changing the thermal-hydraulic characteristics of the reactor. Under these conditions it is possile that existing technical specifications will remain unchanged and no unreviewed safety question will be involved. NRC is evaluating the reactor performance and safety aspects of conversion and expects to publish a report prior to reaching a determination on issuance of a final rule.

To facilitate conversion safety reviews, the NRC is considering the development of generic envelopes of safety limits for the several types of non-power reactors. An affected licensee would then submit an analysis showing that both the normal operating and postulated accident conditions of the reactor fall within the limits. These safety limits would be used in establishing limiting conditions of operation (such as coolant flow, coolant pressure, reactivity conditions). Current developments by the RERTR program indicate that these limiting conditions of operation with LEU fuel may not differ significantly from limiting conditions of operation now used with HEU fuel; however, a definitive conclusion on this matter, applicable to all the conversion candidates will depend on the continued success of the RERTR program over the next several years. Comments are invited on this approach of using generic envelopes of safety limits and limiting conditions of operation.

In cases where conversion from HEU fuel to LEU fuel would neither conflict with the technical specification incorporated in the license nor involve an unreviewed safety question, the conversion could proceed without amendment of the license. In other cases, a license amendment would be required. In view of the significance of this proposed rule to the national interest, the Commission, when implementing the rule, intends to waive any licensing fees that would normally be assessed for amending licenses issued to production and utilization facilities. Interested persons are invited to comment on the possibility that a license amendment will not be required or that an amendment would not present an unreviewed safety question or a conflict with technical specifications.

In summary, the Commission recognizes that successful implementation of the proposed rule, while maintaining the nuclear research and training capability which these reactors provide, depends on (1) the continued success of the DOE funded RERTR program (2) the development of acceptable, and available, replacement fuel, and (3) the extent of financial and operational support provided to affected licensees by the Federal Government through DOE. The Commission also recognizes that the degree of RERTR program success directly impacts the costs attributed to attendant NRC safety reviews. The Commission therefore, is especially interested in public comments on these aspects of the proposed rule.

National Environmental Policy Act Consideration

The Commission has determined, under the National Environmental Policy Act of 1969, as amended, and the Commission's regulations in 10 CFR Part 51, that promulgation of this proposed rule will not have a significant effect on the quality of the human environment and that, therefore, an environmental impact statement is not required. (The environmental assessment and finding of no significant impact on which this determination is based are available for public inspection at the NRC Public Document Room 1717 H Street, NW., Washington, DC.)

Paperwork Reduction Act Statement

The proposed rule amends information collection requirements that are subject to the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.). This rule has been submitted to the Office of Management and Budget for review and approval of the paperwork requirements.

Regulatory Analysis

The Commission has prepared a regulatory analysis for the proposed amendment. The analysis examines the costs and benefits of the amendment and the decision criteria considered by the Commission. A copy of the regulatory anaysis is available for inspection and copying for a fee at the NRC Public Document Room, 1717 H Street NW., Washington, DC.

Regulatory Flexibility Certification

In accordance with the Regulatory Flexibility Act of 1980, 5 U.S.C. 605(b), the Commission hereby certifies that this proposed rule will not, if promulgated, have a significant economic impact on a substantial number of small entities. The proposed regulation affects non-power reactor licensees that own and operate nuclear utilization facilities licensed under section 103 and 104 of the Atomic Energy Act of 1954, as amended. These licensees do not fall within the definition of small businesses set forth in section 3 of the Small Business Act, 15 U.S.C. 632, or within the Small Businesses Size Standards set forth in 13 CFR Part 121.

List of Subjects in 10 CFR Part 50

Antitrust, Classified information, Fire prevention, Incorporation by reference, Intergovernmental relations, Nuclear power plants and reactors, Penalty, Radiation protection, Reactor siting criteria, Reporting and recordkeeping requirements.

PART 50—DOMESTIC LICENSING OF PRODUCTION AND UTILIZATION FACILITIES

Under the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and 5 U.S.C. 533, notice is hereby given that adoption of the following amendment to 10 CFR Part 50 is contemplated.

1. The Authority citation for Part 50 continues to read as follows:

Authority: Secs. 103, 104, 161, 182, 183, 186, 189, 68 Stat. 936, 937, 948, 953, 954, 955, 956, as amended, sec. 234, 83 Stat. 1244, as amended (42 U.S.C. 2133, 2134, 2201, 2232, 2233, 2236, 2239, 2282); secs. 201, 202, 206, 88 Stat. 1242, 1244, 1246, as amended (42 U.S.C. 5841, 5842, 5846), unless otherwise noted.

Sec. 50.7 also issued under Pub. L. 95-601, sec. 10, 92 Stat. 2951 (42 U.S.C. 5851). Sec. 50.57(d), 50.58, 50.9 and 50.92 also issued under Pub. L. 97-415, 96 Stat. 2071, 2073 (42 U.S.C. 2133, 2239). Sec. 50.78 also issued under sec. 122, 68 Stat. 939 (42 U.S.C. 2152). Sec. 50.80-50.81 also issued under sec. 184, 68 Stat. 954, as amended (42 U.S.C. 2234). Sec. 50.100-50.102 also issued under sec. 186, 68 Stat. 955 (42 U.S.C. 2236).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273), §§ 50.10 (a), (b), and (c) 50.44, 50.46, 50.48, 50.54 and 50.80(a) are issued under sec. 161b, 68 Stat. 948, as amended (42 U.S.C. 2201(b)); §§ 50.10 (b) and (c) and 50.54 are issued under sec. 161i, 68 Stat. 949, as amended (42 U.S.C. 2201(i)); and §§ 50.55(e), 50.59(b), 50.70, 50.71, 50.72, 50.73, and 50.78 are issued under sec. 161o, 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

2. A new § 50.64 is added to read as follows:

§ 50.64 Limitations on the use of high enriched uranium in non-power reactors.

(a) *Applicability.* The requirements of this section apply to all nuclear non-power reactors licensed under §§ 50.21(a), 50.21(c), or 50.22 of this part.

(b) *Definitions.* For purposes of this section:

(1) "High enriched uranium" (HEU) fuel means fuel in which the weight percent of U-235 in the uranium is 20% or greater. Target material, special instrumentation or experimental devices using HEU are not included.

(2) "Low enriched Uranium" (LEU) fuel means fuel in which the weight percent of U-235 in the uranium is less that 20%.

(3) "Unique purpose" means that the project or program cannot reasonably be accomplished without the use of HEU fuel, and may include:

(i) A specific experiment or program,

(ii) Reactor physics or reactor development based explicitly on use of HEU fuel,

(iii) Research projects based on the neutron flux levels or spectra only attainable with HEU fuel, or

(iv) A reactor core of special design that could not perform its intended function without using HEU fuel.

(c) *Requirements.* (1) The Commission will not issue a construction permit for a new non-power reactor that would use HEU fuel unless the applicant demonstrates that the proposed reactor will have a unique purpose as defined in paragraph (b)(3) of this section.

(2) Unless the Director of the Office of Nuclear Reactor Regulation has determined, based on a request submitted in accordance with paragraph (d)(1) of this section, that the reactor has a unique purpose, each licensee currently authorized to possess and use HEU fuel in connection with the operation of a non-power reactor shall:

(i) Acquire no additional HEU fuel if LEU fuel acceptable to the Commission for that reactor is available at the time of the proposed acquisition of the HEU fuel by the licensee; and

(ii) Replace all HEU fuel in the licensee's possession with available LEU fuel acceptable to the Commission in accordance with a schedule determined pursuant to paragraph (d)(2) of this section.

(3) If not required by paragraphs (c) (1) and (2) of this section to use LEU fuel, the applicant or licensee must use HEU fuel of enrichment as close to 20% as is available and acceptable to the Commission.

(d) *Implementation.* (1) Any request by a licensee for a determination that a reactor has a unique purpose as defined in paragraph (b)(3), of this section should be submitted with supporting documentation to the Director of the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555, by [insert a date 6 months after the effective date].

(2) By [insert a date 12 months after the effective date] each non-power reactor licensee authorized to possess and use HEU fuel shall develop and submit to the Director of the Office of Nuclear Reactor Regulation a proposed schedule for meeting the requirements of paragraphs (c) (2) or (3) of this section. The proposed schedule shall be based upon availability of replacement fuel acceptable to the Commission and consideration of other factors such as the availability of shipping casks, financial support, and reactor usage. A final schedule will then be determined by the Director of the Office of Nuclear Reactor Regulation.

(3) If the replacement of HEU fuel with LEU fuel does not change the technical specifications incorporated in the license or involve an unreviewed safety question as defined in § 50.59(a)(2), the holder of a non-power reactor license may replace HEU fuel with LEU fuel without amendment to the license and shall maintain records and furnish reports as defined in § 50.59(b). If replacement of HEU fuel with LEU fuel changes the technical specifications incorporated in the license or involves an unreviewed safety question, the licensee shall file an application for an amendment in accordance with § 50.59(c).

Dated at Washington, DC this 29th day of June 1984.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,

Secretary of the Commission.

[FR Doc. 84-17785 Filed 7-5-84; 8:45 am]

BILLING CODE 7590-01-M

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 71

[Airspace Docket No. 84-ASO-14]

Proposed Alteration of Transition Area; Columbia, South Carolina

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking.

SUMMARY: This notice proposes to increase the size of the Columbia, South Carolina, transition area to accommodate Instrument Flight Rule (IFR) operations at Owens Field Airport. This action will lower the base of the additional controlled airspace from 1,200 to 700 feet above the surface in the vicinity of the airport. An instrument approach procedure, based on the Columbia Airport Surveillance Radar (ASR), is being developed to serve the airport and the additional controlled airspace is required for protection of IFR aeronautical activities.

DATES: Comments must be received on or before: August 19, 1984.

ADDRESSES: Send comments on the proposal in triplicate to: Federal Aviation Administration, Attn: Manager, Airspace and Procedures Branch, ASO-530, P.O. Box 20636, Atlanta, Georgia 30320.

The official docket may be examined in the Office of the Regional Counsel, Room 652, 3400 Norman Berry Drive, East Point, Georgia 30344, telephone: (404) 763-7646.

FOR FURTHER INFORMATION CONTACT: Walter H. Wulff, Airspace and Procedures Branch, Air Traffic Division, Federal Aviation Administration, P.O. Box 20636, Atlanta, Georgia 30320; telephone: (404) 763-7646.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested parties are invited to participate in this proposed rulemaking by submitting such written data, views or arguments as they may desire. Comments that provide the factual basis supporting the views and suggestions presented are particularly helpful in developing reasoned regulatory decisions on the proposal. Comments are specifically invited on the overall regulatory, economic, environmental, and energy aspects of the proposal. Communications should identify the airspace docket and be submitted in triplicate to the address listed above. Commenters wishing the FAA to acknowledge receipt of their comments on this notice must submit with those comments a self-addressed, stamped postcard on which the following statement is made: "Comments to Airspace Docket No. 84-ASO-14." The postcard will be date/time stamped and returned to the commenter. All communications received before the specified closing date for comments will be considered before taking action on the proposed rule. The proposal contained in this notice may be changed in the light of comments received. All comments submitted will be available in the Rules Docket both before and after the closing date for comments. A report summarizing each substantive public contact with FAA personnel concerned with this rulemaking will be filed in the docket.

Availability of NPRM's

Any person may obtain a copy of this Notice of Proposed Rulemaking (NPRM) by submitting a request to the Federal Aviation Administration, Manager, Airspace and Procedures Branch (ASO-530), Air Traffic Division, P.O. Box 20636, Atlanta, Georgia 30320. Communications must identify the notice number of this NPRM. Persons interested in being placed on a mailing list for future NPRM's should also request a copy of Advisory Circular No. 11-2 which describes the application procedure.

The Proposal

The FAA is considering an amendment to § 71.181 of Part 71 of the Federal Aviation Regulations (14 CFR Part 71) to alter the Columbia, South Carolina, transition area. This action will provide additional controlled airspace for aircraft executing a new instrument approach procedure to Owens Field Airport. If the proposed alteration of the transition area is found acceptable, the operating status of the airport will be changed from VFR to IFR. Section 71.181 of Part 71 of the Federal Aviation Regulations was republished in FAA Order 7400.6 dated January 3, 1984.

List of Subjects in 14 CFR Part 71

Aviation safety, Airspace, Transition area.

The Proposed Amendment

Accordingly, pursuant to the authority delegated to me, the Federal Aviation Administration proposes to amend the Columbia, South Carolina, Transition Area under § 71.181 of Part 71 of the Federal Aviation Regulations (14 CFR Part 71) as follows:

established under the marketing agreement and Order No. 993 both as amended (7 CFR Part 993) regulating the handling of dried prunes produced in California (hereinafter both are referred to collectively as the "order"). The order is effective under the Agricultural Marketing Agreement Act of 1937, as amended (7 U.S.C. 601–674). The Committee works with USDA in administering the order.

The pack specifications in § 993.515 prescribe commercially recognized size categories for the packing of prunes in consumer packages, including numerical and nomenclature size designations. The nomenclature size designations currently listed in § 993.515(b) would continue in effect. These are "Extra Large", "Large", and "Medium". The additional nomenclature size designation—"Small", "Breakfast", "Petite", or "Economy"—would be defined in § 993.515(c) in terms of the count of prunes per pound as follows: "Small", "Breakfast", "Petite", or "Economy" means any size count which falls within the range of 85 to 100 prunes, inclusive, per pound.

Handlers have been using this nomenclature size designation in conjunction with the numerical designation of 85 to 100 prunes, inclusive, per pound for the past several years, but have found the appearance of both numerical and nomenclature designations on the label to be counterproductive in merchandising and promoting sales of such prunes. This proposal would no longer require the numerical designation to be included on the label with the "Small", "Breakfast", "Petite", or "Economy" size designation, thus making the label more useful in merchandising and promoting the sale of small prunes. Also, the proposal would give handlers greater latitude and flexibility in utilizing, packing, and marketing the smaller prunes they receive from producers each year.

List of Subjects in 7 CFR Part 993

Marketing agreements and orders, Plums and prunes, California.

PART 993—[AMENDED]

Therefore, the proposal is to amend § 993.515 by revising paragraphs (b) and (c) to read as follows:

Subpart—Pack Specification as to Size

§ 993.515 Size Categories.

* * * * *

(b) *Nomenclature designations.* Each of the following is a nomenclature size category:

(1) Extra Large;
(2) Large;
(3) Medium; and
(4) Small, Breakfast, Petite, or Economy.

(c) *Nomenclature designations defined.* As used in paragraph (b) of this section:

(1) "Extra Large" means any size count which falls within the range of 25 to 40 prunes, inclusive, per pound;

(2) "Large" means any size count which falls within the range of 40 to 60 prunes, inclusive, per pound;

(3) "Medium" means any size count which falls within the range of 60 to 85 prunes, inclusive, per pound; and

(4) "Small", "Breakfast", "Petite", or "Economy" means any size count which falls within the range of 85 to 100 prunes, inclusive, per pound.

* * * * *

(Secs. 1–19, 48 Stat. 31, as amended; 7 U.S.C. 601–674)

Dated: August 9, 1984.

Thomas R. Clark,

Deputy Director, Fruit and Vegetable Division.

[FR Doc. 84-21542 Filed 8-13-84; 8:45 am]

BILLING CODE 3410-02-M

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors; Extension of Comment Period

AGENCY: Nuclear Regulatory Commission.

ACTION: Proposed rule: Extension of comment period.

SUMMARY: The Nuclear Regulatory Commission is extending the public comment period on its notice of proposed rulemaking, published on July 6, 1984 (49 FR 27769), for an additional 60-day period. This will provide additional time for interested members of the public to evaluate the issues raised and to develop comments on the proposed rule. The proposed rule generally would require that new non-power nuclear reactors use low enriched uranium (LEU) fuel and that existing reactors replace highly enriched uranium (HEU) fuel with LEU fuel when available. The public comment period was scheduled to expire on September 4, 1984.

DATES: The new comment period expires November 2, 1984. Comments received after that date will be considered if it is practical to do so, but assurance of consideration cannot be given except as to comments received on or before that date.

ADDRESS: Written comments or suggestions for consideration in connection with the proposed rule should be submitted to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Docketing and Service Branch. Comments received may be examined in the Commission's Public Document Room at 1717 H Street, NW, Washington, DC.

FOR FURTHER INFORMATION CONTACT: William R. Lahs, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, telephone (301) 443–7874.

Dated at Washington, DC, this 9th day of August 1984.

For the Nuclear Regulatory Commission.

Samuel J. Chilk,

Secretary of the Commission.

[FR Doc. 84-21552 Filed 8-13-84; 8:45 am]

BILLING CODE 7590-01-M

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 71

[Airspace Docket No. 84–ASW–32]

Proposed Alteration of Transition Area and Control Zone; Temple, TX

Correction

In FR Doc. 84–20533, appearing on page 31077, in the issue of Friday, August 3, 1984, making the following corrections:

1. The heading should read as printed above.

2. In the "SUMMARY" paragraph, in the third line "transportation" should read "transition".

3. In the "FOR FURTHER INFORMATION CONTACT" paragraph, in the first line "Stephson" should have read "Stephenson".

4. In the third column, in the first paragraph under "§ 71.171 Temple, TX [Revised]", in the fifth line, "radious" should read "radius".

BILLING CODE 1505-01-M

POLICY ISSUE
(Notation Vote)

August 23, 1984

SECY-84-336

For: The Commissioners

From: William J. Dircks
Executive Director for Operations

Subject: FUNDING FOR DOE'S REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS PROGRAM

Purpose: (1) To report to the Commission on NRC funding support for DOE's Reduced Enrichment for Research and Test Reactor (RERTR) program as requested in the June 11 Staff Requirements Memorandum to W. J. Dircks from S. J. Chilk, and (2) to obtain Commission concurrence in a draft response to a June 12 letter from DOE requesting financial support from NRC for the RERTR program.

Discussion: By SECY-84-220, the Commission was advised that the House Committee on Science and Technology had proposed an FY 1985 funding level for the RERTR program of $4.932 million, approximately $780K short of the funding required for a full-core demonstration. The Commission was informed also that without this additional level of support, completion of the necessary RERTR test and evaluation activities would be delayed for one year.

Subsequently, the Commission directed the staff to look into and report on the funding for this program. Shortly after receiving this directive, the staff received a formal request from DOE for supplementary budget support from NRC of between $250K and $300K to help offset the estimated $780K shortage (Enclosure 1). In an earlier letter dated May 22, DOE had also requested supplementary financial support from the Department of State. State did not respond directly to that request; however, Ambassador Kennedy subsequently wrote to the Secretary of Energy on May 29, 1984 (Enclosure 2) expressing support for the program and urging that the necessary funding for the test and demonstration projects be made available. State did not offer any funding support from its own budget. The staff understands that Secretary Hodel has not yet responded to State's letter.

CONTACT:
G. K. Tomlin, RES
427-4301

Since then, the FY 1985 Energy and Water Development Appropriations Act has been enacted (P.L. 98-360). The Senate Appropriations Committee Report (S. 98-502) accompanying P.L. 98-360, states on page 101, "For advanced reactor systems, the fiscal year 1985 budget request again proposes to transfer funding for reduced enrichment research and test reactor (RERTR) program to the Arms Control and Disarmament Agency. The Committee considers this type of research to be a responsibility of the Department of Energy. Therefore, the funding request has been transferred from the Commerce, State, Justice and Related Agencies Appropriations Subcommittee to the Energy and Water Development Subcommittee. The Committee recommends $4,932,000 for this activity, the same as the House and the budget request." The budget recommended by the Senate Appropriations Committee for DOE on the RERTR program was based upon the budget request submitted by ACDA which was $780K short of what DOE felt is needed.

The staff believes that DOE should continue to be the single agency responsible for funding and administering the U.S. Government's RERTR program and that the Commission should not offer any funding support from NRC's budget. Historically, Congress has treated the RERTR program as a single agency funded program and to attempt to divide funding responsibilities at this time could unnecessarily complicate matters and conceivably result in further program delays.

There are also possible legal ramifications affecting NRC's funding support for RERTR. For example, it could be argued that NRC funding would be contrary to its regulatory responsibilities in that it would in effect be providing support to the nuclear industry for an activity which NRC may in the future be required to license. In addition, such funding by NRC may possibly be inappropriate in that it may give an unfair competitive advantage to the participating manufacturers.

The staff believes that appropriate funding for the RERTR program can be found either by reallocation of funds within DOE's budget or supplementary funding authorized by Congress. The staff notes that Congressional support for the RERTR program remains high.

Recommendation: That the attached (Enclosure 3) letter from Chairman Palladino be sent to Secretary Hodel expressing the Commission's concern that DOE take whatever steps are appropriate to obtain adequate funding support for the RERTR program.

William J. Dircks
Executive Director
for Operations

Enclosures:
As stated

Commissioners' comments or consent should be provided directly to the Office of the Secretary by c.o.b. Tuesday, September 11, 1984.

Commission Staff Office comments, if any, should be submitted to the Commissioners NLT Tuesday, September 4, 1984, with an information copy to the Office of the Secretary. If the paper is of such a nature that it requires additional time for analytical review and comment, the Commissioners and the Secretariat should be apprised of when comments may be expected.

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Department of Energy
Washington, D.C. 20545

[illegible] 1 1984

Mr. William J. Dircks
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. ~~Dircks~~: Bill

You probably are aware that Congressional funding support for the Reduced Enrichment for Research and Test Reactors (RERTR) Program in FY 1985 is not adequate to permit procurement, on schedule, of the low enrichment uranium (LEU) silicide fuel assemblies needed for full core demonstration in the Oak Ridge Research Reactor (ORR). If supplemental funds cannot be secured in FY 1985, it will be necessary to defer for one year the planned demonstration of LEU-silicide fuel in a high power/performance application. Naturally, such a deferment will necessitate corresponding deferments of candidate-reactor conversions to such fuels.

Current rulemaking activities of the Nuclear Regulatory Commission urge that both foreign and domestic research reactors be converted to LEU-fuels as expeditiously as possible. However, most reactor operators and other nuclear regulatory bodies consider successful conclusion of the planned LEU-silicide fuel demonstration in the ORR to be a prerequisite for implementing their conversion plans.

We are examining programmatic options for proceeding with the planned LEU-fuel procurement on schedule. However, anticipating that FY 1985 RERTR funding will be limited to the amount currently in the House Appropriations Committee bill, available funding will be too limited to carryout favorable negotiations with the fuel fabricators at this time. The current FY 1985 shortfall is approximately $780K.

The Department would welcome contributions of supplemental funding, which NRC and other Federal agencies might make available, to assure favorable and timely negotiations with the fuel fabricators. A $250-300K supplement from NRC would help prevent deferment, for one full year, of this critical demonstration. We are making efforts (see enclosure) to obtain budgetary assistance for the program from all parties involved to avoid deferment that could extend achievement of the program objectives into the 1990's.

If you are able to provide funding for this purpose, please contact me as soon as possible at 353-3609. We would be pleased to meet with your staff and discuss this matter in more detail if you so desire.

Sincerely,

K. Laughon

Kermit O. Laughon, Director
Office of Spent Fuel Management
and Reprocessing Systems
Office of Nuclear Energy

Enclosure

cc w/enclosure
James R. Shea, NRC
Robert B. Minogue, NRC

DEPARTMENT OF STATE
AMBASSADOR AT LARGE
WASHINGTON

May 29, 1984

Dear Mr. Secretary:

I am writing to express my concerns about the proposed level of funding for the Reduced Enrichment for Research and Test Reactor (RERTR) program for fiscal year 1985. Although RERTR was originally part of the Arms Control and Disarmament Agency's budget request for FY 85, I understand that the House Appropriations Committee of the Subcommittee for Energy and Water has once again placed RERTR in DOE's budget. As matters now stand, the program needs an additional $700,000 during the next fiscal year for the extremely important fuel demonstration at the Oak Ridge Reactor (ORR). I believe that matter is rather urgent because Argonne needs to place orders for fuel for the test early this summer in order to begin testing on schedule in the fall of 1984.

From the standpoint of maintaining the schedule for reactor conversions, as well as maintaining the cooperative spirit of the foreign participants, the Department of State considers it absolutely essential that the fuel demonstration at ORR go forward on the timetable that everyone has been expecting for several years and that the test not be delayed until fiscal year 1986. I understand that some fifteen reactor operators have indicated to program managers at Argonne that they will convert their respective reactors to low enriched fuel upon the successful completion of the ORR demonstration. The RERTR program is a key element in fulfilling the President's 1981 non-proliferation policy objective to "encourage the substitution of lower enriched fuels in research reactors at the earliest possible date." I believe any major delay in the

The Honorable
Donald P. Hodel,
Secretary of Energy.

program would create an extremely negative reaction in the Congress, the Nuclear Regulatory Commission, and abroad, at a time when we most need to demonstrate the continuing U.S. commitment to this important program.

I urge you to take the appropriate steps to assure that an additional $700,000 be made available so that the full range of planned testing and demonstration projects can be carried out in the RERTR program during the next fiscal year.

Please let me know if you wish to discuss this or any other matter relevant to the RERTR effort.

Sincerely,

Richard T. Kennedy

The Honorable Donald P. Hodel
Secretary of Energy
Washington, D. C. 20545

Dear Mr. Secretary:

It has come to my attention that the Reduced Enrichment for Research and Test Reactors program may suffer a $780,000 shortage in FY85. I understand it may be necessary to obtain this additional funding in order to permit the procurement of the low enrichment uranium silicide fuel assemblies needed for full-core demonstration in the Oak Ridge Research Reactor (ORR); and failure to obtain the necessary supplemental funds would cause a one-year delay in the planned demonstration of LEU-silicide fuel in a high power/performance application.

As you know, NRC has long supported the RERTR program and considers it to be important in carrying out the U.S. policy of developing proliferation resistant fuels and fuel cycles. Failure to provide adequate funding at this time could not only delay implementation of the results of this program, but also cause the continued export of high-enriched uranium abroad, contrary to U.S. objectives, until such time as the tested low enriched uranium becomes available. In addition, such a delay would impact U.S. efforts to convert NRC-licensed research and test reactors to use of LEU.

Accordingly, because of the importance of this program in achieving U.S. non-proliferation objectives, I urge that adequate funding be provided for this program and respectfully request that you give this matter your personal attention.

Sincerely,

Nunzio J. Palladino
Chairman

NUREG/CR-3666
R1

Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Uranium Fuel

Manuscript Completed: January 1984
Date Published: February 1984

Prepared by
LEU Study Group

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Prepared for
Division of Accident Evaluation
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN D1126

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EXECUTIVE SUMMARY

The United States provides the bulk of the highly enriched uranium (HEU, enrichment 70% or greater) which is used in research, training, and test reactors other than those supplied by Russia. About 1100 kilograms of HEU are used annually for this purpose (600 kg export, 500 kg domestic), and it has been estimated that more than four metric tons of HEU are in circulation at any given time. Terrorist activity or nuclear proliferation involving some of this HEU could have harmful effects on society. The NRC has issued a policy stating its concern and expressing support for a policy of conversion to low enriched uranium fuel (LEU, enrichment less than 20%). It may be possible that a nuclear explosive could be made using LEU fuel. This appears, however, to be very difficult and the 20% upper limit for LEU enrichment is traditional and reasonable.

In the United States, there are 36 United States Department of Energy (DOE) research and test reactors, three reactors of other government agencies, 25 university reactors, and five private reactors which utilize HEU fuel. Thus considerably more than half of these reactors are government operated, mostly by DOE, and these account for about 90% of the HEU involved. The university reactors, the private reactors, and the National Bureau of Standards (NBS) reactor are licensed by the United States Nuclear Regulatory Commission (NRC) and would be affected directly by NRC requirements for HEU to LEU conversion. The university reactors, with which this study is concerned, have an important national role in training personnel for nuclear work and in carrying out research and test functions. The university reactors, because they are licensed by the NRC, and because of financial and other constraints, could be strongly affected by an NRC rule on LEU conversion.

For this reason, the Division of Research of the NRC, and the Nuclear Engineering Department Heads Organization (NEDHO), set up an LEU Study Group to assess the implications of LEU conversion for the 25 university reactors currently having HEU fuel. Specifically omitted are the other NRC-licensed reactors using HEU fuel. The LEU Study Group's work was greatly aided by an up-to-date compilation of reactor data, the "Research, Training, Test and Production Reactor Directory," by the work of the Reduced Enrichment Research and Test Reactor (RERTR) Program at Argonne National Laboratory, by the TRTR organization as a focus of interest and action on matters concerning Test, Research, and Training Reactors (TRTR), and by the LEU demonstration program successfully completed at the Ford Nuclear Reactor (FNR) of the University of Michigan.

The four-member LEU Study Group was organized to represent the considerable range of university reactors, from high power reactors emphasizing research to low power reactors emphasizing training. In addition, the LEU Study Group included a member of NEDHO, the current head of the Test, Research, and Training Reactors (TRTR) organization, and a representative from the LEU demonstration reactor staff at the University of Michigan. The LEU Study Group was further balanced by the inclusion of two reactor staff managers and two university faculty directors of reactors. The LEU Study Group assessed university reactors from the aspects of Technical Feasibility, Functional Impacts, Licensing, and Scheduling. An important source of information for the LEU Study Group was an LEU Conversion Survey (Appendix A) of the 25 university reactors using HEU fuel.

Technical Feasibility

Technical feasibility, for the purposes of this document, is defined in Section 1.4.1 of IAEA-TECDOC-233, which states: "In assessing the practical feasibility of utilizing lower enriched fuel in existing research reactors, the agreed criteria are that safety margins and fuel reliability should not be lower than for the current design based on highly enriched uranium, major reactor modifications should not be required, and that preferably neither any loss in the overall reactor performance (e.g. flux-per-unit power) nor any increase in operation costs should be more than marginal." Because of the wide ranges in reactor power levels and applications, it is difficult to assign precise values to the above criteria. However, research reactor community would probably regard any modification cost approaching even one percent of the reactor capital cost as major, and any loss in performance or increase in operating costs in excess of 5-10% as more than marginal.

Based on our assessment, conversions can be divided into three categories: those that appear to be technically feasible with today's fuel technology, those that are not feasible even with advanced technologies now under development or projected, and those that require further study before a prediction of technical feasibility can be made with confidence. The reactors at Michigan (already demonstrated), Purdue, Ohio State, and WPI, pool reactors which now have fuels with the lowest uranium densities, fall in the first category, along with the liquid fueled reactor at UCSB. Missouri-Columbia and MIT, with the highest uranium densities, fall in the second, and all other reactors are in the third category pending detailed analysis.

Functional Impacts

The functional impacts of conversion of university reactors from HEU fuel to LEU fuel can be considered as direct costs and benefits and as societal costs and benefits. The former can be quantified in some cases, and this is the primary emphasis of the present assessment. The projection of direct costs and benefits are based on the known costs of the FNR demonstration, on the university reponses to the LEU Conversion Survey, on discussions with fuel manufacturers, and on other information. Societal costs and benefits from LEU conversion are difficult to quantify but are nevertheless important.

The largest component of direct cost is that for fuel. The fuel in U.S. university reactors has been and presumably will continue to be owned by the DOE, which bears the costs of ore, conversion, enrichment, and disposal. Costs of fabrication are identified through discussions with commercial vendors and may be borne or shared by universities. Fuel shipment costs also are substantial and may be borne by the university in some cases.

Here it is useful to distinguish several conversion options, A, B, and C. If the HEU fuel already produced for university reactors were to be consumed and replaced by LEU fuel at refueling time (Option A) then the incremental costs of conversion to LEU fuel would be small, because an LEU fuel assembly or an LEU core costs about the same as for HEU fuel. It is assumed under Option A that the MIT and University of Missouri-Columbia high power research reactors would not be required to convert to LEU fuel because this is not foreseen to be technically feasible. Thus Option A has little additional direct cost for fuel and transportation, although there are substantial administrative and other costs.

Option B is the same as Option A except that HEU fuel is replaced at time of normal refueling by LEU fuel as rapidly as this can be delivered, and unused HEU fuel is returned to DOE for disposal. About 100 HEU fuel elements for university reactors might be scrapped under Option B, at a cost of about one million dollars. Only fabrication and transportation costs are included here, because other fuel values are not lost.

Option C assumes that all university reactors, except MIT and University of Missouri-Columbia, are required to replace HEU fuel with LEU fuel as rapidly as LEU fuel can be delivered. Reactors with lifetime cores thus would be converted to LEU under this option but not under Options A or B. The cost of fuel fabrication and transportation for this option is estimated to be about nine million dollars.

The university responses to the LEU Conversion Survey, together with the FNR demonstration data, suggest that non-fuel costs total to about $250,000 per reactor. This figure is less than that for the FNR conversion, because it assumes that some reactors of similar type will be able to take advantage of the lead reactor concept and generic licensing. On the other hand, some unique reactors may require substantially larger figures. The total of the non-fuel costs of conversion of the 23 university reactors other than University of Missouri-Columbia and MIT thus is estimated to be about six million dollars.

It is concluded that the technical feasibility of LEU conversion can be established for most university reactors. However, in terms of a cost-benefit analysis, the major benefit that would accrue is the reduction in the risk of unauthorized diversion of HEU. This is an intangible benefit that cannot be quantified. Direct costs, on the other hand, can be assessed to some extent and are large by university standards.

Excessive application of these LEU conversion costs to university reactors may result in the shutting down of some of these.

Licensing

License modifications are required for conversion of university reactors to LEU fuel. The university applications for license modifications and the NRC responses to these require effort, time, and cost. No basic problems in licensing are anticipated because the conversion from HEU fuel to LEU fuel appears to have little effect on reactor safety. No respondee to the LEU Conversion Survey anticipated licensing difficulties other than effort, time, and cost requirements. Nevertheless, it is possible, though we consider it to be unlikely, that detailed analyses may reveal LEU-related safety problems for one or more reactors.

In the event of LEU conversion the reactor licensee would submit a modified Safety Analysis Report (SAR) as well as a proposed license amendment. Modifications also may be required in the accompanying Technical Specifications and Bases. Full documentation of the proposed nuclear and thermal-hydraulics characteristics for LEU fuel would be submitted to the NRC. Various accident situations would be considered. If the reactor's thermal-hydraulics and control characteristics are demonstrated to be essentially unchanged so that hypothetical accident considerations also are unchanged, then a major SAR revision may be unnecessary.

License amendments, if approved, could be issued in accordance with normal licensing procedures. For the purposes of this report we will distinguish between major and minor license revisions; the former may correspond to those requiring a major SAR revision and, possibly, a new construction permit. If the new fuel requires new and different control systems then a new construction permit may be required. Public hearings might be required if a major license revision is involved. We assumed that no No public hearings would be required for a minor license amendment, which for present purposes is defined as a license revision that is not major.

Some LEU conversion could be accomplished by changing fuel plate composition, leaving the fuel plate outer dimensions and the reactor configuration unchanged. In this case the reactor thermal-hydraulics properties would be virtually unchanged. If shutdown margin and other safety-related characteristics also are satisfactory then the license amendment can be considered to be minor. In Table ES.1 are listed the prospective licensing categories for the 25 university reactors potentially affected by LEU conversion. With existing fuel technology ($UA\ell_x < 1.6$ gU/cc, $UZrH_x < 0.35$ gU/cc) 7 reactors can be converted by LEU fuel substitution with no change in thermal-hydraulics properties; hence minor license amendments are anticipated for these. Another 16 reactors appear to require major license revisions. For the other two reactors, MIT and University of Missouri-Columbia, existing fuel technology is not adequate if loss of performance is not to occur. With anticipated advanced fuel technology ($U_3Si < 7$ gU/cc, $UZrH_x < 3.7$g U/cc) 16 of the reactors can be converted to LEU without change in core thermal-hydraulics. At that point only the University of Missouri-Columbia and MIT reactors would require major license revision.

For several very low power reactors such as RPI and Manhattan College, conversion to LEU fuel may involve considerable modifications to the reactor. These modifications are not expected to reduce safety, but detailed analyses are required to verify this.

Safety Analysis Reports require (among other matters) (a) determination of safety-related parameters such as reactivity coefficients, neutron lifetime, excess reactivity, control rod worths, and transient thermal-hydraulic characteristics; (b) consideration of hypothetical accident events; and (c) analyses of hypothetical accident events by use of qualified computer programs. Probabilistic risk assessment is not usually applied; instead attention is focused on identifying and analyzing a maximum hypothetical event, usually a power burst following reactivity insertion, or a loss of coolant (LOCA). Requirements (a), (b), and (c) are assessed in turn.

The specification of the reactivity insertion leading to the hypothetical power burst is affected by the available excess reactivity and by the control rod worths. The latter are important when control rods are assumed to be withdrawn without restraint; alternatively the reactivity insertion may be assumed to be from change in an unsecured experiment. The development of the

Table ES.1 Licensing Categories for LEU Conversion of University Reactors

	Lifetime Core		Routine Fuel Cycle	
LEU CONVERSION	Minor License Amendment	Major License Revision	Minor License Amendment	Major License Revision
With Existing Fuel Technology ($UA\ell_x < 1.6gU/cc$, $UzrH_x < 0.35gU/cc$)	Ohio State U. U.C. Santa Barbara Purdue Univ. WPI	VPI* U. of Virginia Cavalier Georgia Tech* Iowa State* Manhattan* UCLA* U. Florida* U. Kansas* U. Missouri-Rolla* U. Washington* RPI* Oregon State U. U. Wisconsin Wash. State U.	U. Lowell U. Michigan Rhode Island	U. Virginia-UVAR Texas A&M
With Anticipated Advanced Fuel Technology (U_3 Si < 7 gU/cc $UZrH_x < 3.7gU/cc$)	VPI* Georgia Tech* Iowa State* Manhattan* UCLA* U. Flordia* U. Kansas* U. Missouri-Rolla* U. of Washington* RPI* U. Virginia Cavalier Oregon State Univ. U. Wisconsin Wash State U.		U. Virginia-UVAR Texas A&M	U. Missouri-Columbia* MIT*

* Assuming that safety considerations are demonstrated for LEU fuel after detailed analysis of safety parameters and hypothetical accidents.

power burst after initiation is enhanced for LEU fuel by a shorter neutron lifetime, by a reduced effective delayed neutron fraction, and by the longer thermal relaxation time for the fuel. The power burst is diminished by the prompt negative U-238 Doppler coefficient of reactivity and by a larger void coefficient of reactivity. These effects will cancel to some extent.

The net effect of conversion from HEU fuel to LEU fuel on initiation and development of hypothetical power bursts can only be determined by use of qualified computer programs. Qualification here includes the validation of the computer program against suitable experimental data, the use of the program in an SAR submittal to the NRC, and the NRC acceptance of the results. Calculations by the RERTR group for a representative MTR-type reactor benchmark indicate that for this reactor the development of hypothetical power bursts was not greatly changed by LEU conversion, although for some bursts the peak fuel temperature was slightly higher for LEU fuel. These results suggest, but do not demonstrate for specific university reactors, that cancellation of the effects of the LEU conversion-associated changes in safety parameters will result in little change in predicted power burst development.

The use of LEU fuel is not expected to effect LOCA considerations substantially unless the reactor thermal-hydraulic characteristics are changed.

The preparation and defense of adequate Safety Analysis Reports can be costly both in time and effort. These costs might be reduced by several means. Generic licensing of similar reactor conversions could be very useful; here the major costs would be borne by the lead reactor (possibly under a government contract). The development of qualified computer programs for safety analysis can be very costly and should be coordinated. Even the identification of a suitably qualified existing computer program for a specific safety analysis can be costly, and guidance could be useful here. Finally, a reference document addressing NRC information needs for licensing review would be useful. This document could summarize technical information requirements and QA/QC requirements as well.

Schedule

Test programs sponsored by the Department of Energy through Argonne National Laboratory are designed to demonstrate by the dates indicated that uranium densities can be increased to the values listed for the following types of fuels:

Table ES.2 Current and Planned Fuel Technology

		Uranium Density in Fuel Meat (g/cc)		
Fuel Meat	Clad	Current	Planned	Planned Qualification Dates
UAl_x-Al	Al	1.60	2.3	January 1984
U_3O_8-Al	Al	1.30	3.2	June 1985
$UZrH_x$	Stainless Steel	0.35	3.7	January 1985
U_3Si_2-Al	Al		4.8	January 1986
U_3Si-Al	Al		7.0	June 1989

The tasks associated with conversion of a research reactor from HEU to LEU fuel are: initial program planning; safety analysis and license amendment; core physics calculations; operating thermal-hydraulics analysis; plant engineering modifications; LEU fuel specifications, procurement of fuel, and calculational confirmation of design; training of staff personnel; HEU core physics measurements and fuel disposal; and experimenal verification of reactor behavior with LEU fuel.

The fuel manufacturers indicate that they do have the capacity to meet the fuel needs of the university reactors, but a detailed schedule would have to be worked out. Fuel manufacturers would not be willing, for example, to gear up for a massive, one-time production of fuel for converting all reactors with lifetime cores. Production for these reactors would have to be spread over a period of years. Preparation of special tooling required for a particular reactor whose fuel is not already in production would require 9-12 months. This would apply to about half of the 25 reactors in this study.

LEU fuel conversion of the 25 NRC licensed, university-owned reactors considered in this study is based upon the reactor fuel cycle, the type of license modification, and fuel meat technology. Reactors that operate on routine refueling cycles could periodically replace depleted HEU elements with fresh LEU elements. Ultimate full core conversion would depend on the average element residence time in the core. Reactors with lifetime cores would convert by full core replacement as a one-time event. For some reactors, LEU conversion depends upon high density uranium fuel meat technology development as is outlined in Sections 2 and 5.1. The majority should be able to convert using a direct substitution of current fuel meat technology though some fuel plate or rod internal modifications may be necessary for 16 of the reactors.

Eighteen reactors currently operate with lifetime cores, that is, refueling is not anticipated during the useful life of the facility. It is anticipated that no changes in overall plate or element dimensions would be necessary to convert three of these reactors by substitution of LEU fuel utilizing current fuel meat technology. The University of California-Santa Barbara utilizes a uranyl sulfate fuel solution. No difficulty is anticipated in conversion to LEU because low enriched uranyl sulfate fuel is currently used in the identical Brigham Young University L-77 reactor. The remaining 14 reactors can be converted to LEU without dimensional changes utilizing anticipated advanced fuel technology.

Seven reactors operate on routine fuel replacement cycles. One reactor, at the University of Michigan, has converted to LEU fuel. Of the remaining six, two can be immediately converted utilizing current fuel meat technology with minor license amendments. Two additional reactors (Texas A&M and University of Virgnia-UVAR) can be converted with minor license amendments after advanced fuels become available. Full LEU conversion of the MIT and University of Missouri-Columbia reactors is not possible without fuel modification even after the scheduled 1989 verification of 7.0 g/cc uranium silicide fuels.

The most reasonable approach to LEU conversion scheduling would be to establish an orderly process which allows sufficient time for each reactor to complete the conversion sequence and provides a fuel fabrication schedule that is within the production capabilities of the fuel manufacturers while making allowance for fuel need dates and the availability of high density uranium fuels.

For lifetime core reactors approximately 60 months would be required for full core LEU conversion of a reactor undergoing a major license revision from initial planning to final HEU fuel shipment from the site. For a minor license amendment, the conversion can be shortened to approximately 48 months by eliminating the 12 months allowed for public hearings. Seventeen of the 25 reactors being considered are estimated to be in this 48 month category.

Reactors that operate on routine refueling cycles rather than with lifetime cores would prefer to convert by gradual integration of LEU fuel into the existing HEU core. The schedule time depends upon the the core residence time of a single element. Residence times range from two to five years. For the reactors undergoing minor license amendments, full conversion would require 72 to 108 months. For a major license revision, 84 to 120 months would be required. Five reactors are in the 72 to 108 month class; two are in the 84 - 120 month class.

Conversion at the University of Michigan, which involved a minor license amendment, started in 1979 and completion of all conversion related activities is expected to require 72 months. The conversion was a full core replacement, but with more extensive core calculations, measurements, and tests than would be required for a routine conversion.

Problem areas that provide significant uncertanties within the university community for LEU conversion time schedules are the magnitude of the license revision, the scope and length of public hearings, major facility engineering modifications, full core conversion versus conversion over a period of time by following the normal refueling cycle, the capacity of fuel manufacturers to provide the fuel needed for conversion in a timely manner, the availability of spent fuel shipping casks, the cost of spent fuel shipment, and the basic conversion costs of new fuel and analysis.

Recommendations

The LEU Study Group recommends that the cost of returning unused or partially used HEU fuel be carefully considered in the course of rule working. An economic penalty on the order of $10,000 -$20,000 per fuel element would result if a new regulation would prohibit the use of such unused fuel either in storage at the reactor site or at another location.

It is recommended that consideration be given to the significant savings in direct and indirect costs if conversion to LEU were not to be required until a suitable type of advanced fuel has been demonstrated and becomes available. A desirable advanced fuel will enable a reactor to convert to LEU either by direct substitution or by increasing the fuel meat thickness without increasing the total plate thickness. In this case no thermal-hydraulics changes would be required.

Where conversion to LEU is not technically feasible in the near future, the LEU Study Group recommends that consideration be given to reduction of proliferation risk through the use of medium enriched uranium (MEU) fuel and, through decreased HEU traffic by utilizing advanced fuels technology in combination with HEU.

It is the primary recommendation of this study that, if conversion to LEU fuel is mandated by the NRC, then adequate funding for this conversion must be provided by the federal government. Otherwise, many university-based reactors may have to be shutdown. It is recommended that the NRC encourage the provision of federal funds for all aspects of LEU conversion: analyses, facility modifications, new fuel, startup tests with new fuel, and spent fuel shipment.

It is recommended that the NRC establish a priority system for LEU conversion. The factors that would affect this priority list include: (1) LEU fuel availability and cost; (2) fuel consumption; (3) fuel cycle costs for fabrication and shipping. It is recommended that the highest priority for LEU conversion should be for plate-type reactors having 0.2Mw<Power<2 Mw, since the fuel technology is reasonably assured, and this group comprises a significant fraction of all university reactors. The second priority should comprise the remaining low power reactors. The third priority should be for reactors with Power > 2Mw and with high power density. This group comprises only 2 reactors for which LEU fuel is not currently available and the costs of conversion will be much higher than for the lower power group.

A recommendation that would offer substantial cost savings is that lead reactors be identified for each group of similar reactors. These reactor staffs would develop SAR's and related documentation which could be used by the other reactor staffs as guides or for generic licensing.

It is recommended that a reference document addressing NRC information needs for licensing review for LEU conversion, and summarizing technical information requirements and QA/QC criteria, be provided.

It is recommended that generic licensing be applied where feasible for similar reactor conversions.

It is recommended that important safety analysis codes be qualified for SAR application and made available to those carrying out SAR analyses.

It is recommended that the NRC carefully consider in the course of rule making the capabilities of the fuel manufacturers to handle the LEU conversion fuel fabrication schedule.

It is recommended that the NRC encourage the timely licensing of spent fuel shipping casks as required for the LEU conversion schedule.

It is recommended that the NRC encourage the carrying out of the advanced fuel development program as scheduled.

1. Introduction

1.1 Background and Scope

The United States provides the bulk of the highly enriched uranium (HEU, enrichment 70% or greater) which is used in research, training, and test reactors other than that supplied by Russia. About 1100 kilograms of HEU are supplied annually for this purpose (600 kg export, 500 kg domestic), and it has been estimated that more than four metric tons of HEU are in circulation at any given time.[1] Terrorist activity or nuclear proliferation involving diversion of some of this HEU could have harmful effects on society. The NRC has issued a policy statement[2] expressing its concern and expressing support for a policy of conversion to low enriched uranium fuel (LEU, enrichment less than 20%[3]). It may be possible that a nuclear explosive could be made using LEU fuel. This appears, however, to be very difficult and the 20% upper limit for LEU enrichment is traditional and reasonable.

In the United States there are 36 United States Department of Energy (DOE) research and test reactors, three reactors of other government agencies, 25 university reactors, and five private reactors which utilize HEU fuel. Thus considerably more than half of these reactors are government operated, mostly by DOE, and these account for about 90% of the HEU involved. The university reactors, the private reactors, and the National Bureau of Standards (NBS) reactor are licensed by the United States Nuclear Regulatory Commission (NRC) and would be affected directly by NRC requirements for HEU to LEU conversion. The university reactors, with which this study is concerned, have an important national role in training personnel for nuclear work and in carrying out research and test functions. The university reactors, because they are licensed by the NRC, and because of financial and other constraints, could be strongly affected by an NRC rule on LEU conversion.

For this reason, the Division of Research of the NRC and the Nuclear Engineering Department Heads Organization (NEDHO) set up an LEU Study Group to assess the implications of HEU to LEU conversion for university reactors. The 25 university reactors currently using HEU fuel, their locations, and their NRC docket numbers are listed in Table 1.1. Table 1.2 gives the power levels and annual fuel requirements for these reactors. These reactors have various degrees of connection with academic activities and one, the Rhode Island reactor, is virtually autonomous and is included here for completeness. Specifically omitted are the other NRC-licensed reactors using HEU fuel: the NBS reactor, the Union Carbide Reactor, the General Atomic Triga-F reactor, the Westinghouse Nuclear Training Reactor, the General Electric Test Reactor, and the General Electric Nuclear Training Reactor. The LEU Study Group assessed university reactors from the aspects of Technical Feasibility (Section 2), Functional Impacts (Section 3), Licensability (Section 4), and Scheduling (Section 5). Recommendations are given at the end of each Section and are combined in a final Recommendations, Section 6.

1.2 The LEU Study

The LEU Study Group's work was greatly aided by an up-to-date compilation of reactor data, the Research, Training, Test and Production Reactor Directory,[4] by the work of the Reduced Enrichment Research and Test Reactor (RERTR) Program[5] at Argonne National Laboratory, by the TRTR organization as a focus of interest and action on matters concerning Test, Research, and Training Reactors (TRTR),[6] and by the LEU demonstration program successfully completed at the Ford Nuclear Reactor (FNR) of the University of Michigan.[7]

Table 1.1

University Research and Training Reactors with HEU Fuel

	University/Laboratory	Location	Reactor Acronym	NRC Docket	License Exp. Date
	Plate Type Fuel, 93% Enriched Uranium				
	High Power				
1.	University of Missouri-Columbia	Columbia, MO	MURR	50-186	2001
2.	Massachusetts Inst. of Technology	Cambridge, MA	MITR	50-20	1996
3.	Georgia Inst. of Technology	Atlanta, GA	GTRR	50-276	1994
	Medium Power				
4.	Rhode Island Nuclear Science Center	Narragansett, RI	RINSC	50-193	2002
5.	University of Michigan	Ann Arbor, MI	FNR	50-2	1985
6.	University of Virginia-UVAR	Charlottesville, VA	UVAR	30-62	2002
7.	University of Lowell	Lowell, MA	ULR	50-223	1985
	Low Power				
8.	University of Missouri-Rolla	Rolla, MO	UMRR	50-123	2004[*]
9.	Ohio State University	Columbus, OH	OSURR	50-150	2000
10.	University of Kansas	Lawrence, KA	BRTR	50-148	2004[*]
11.	Worcester Polytechnic Institute	Worcester, MA	WPI	50-134	2002
12.	Purdue University	West Lafayette, IN	PUR-1	50-182	1986
13.	Rensselaer Polytechnic Institute	Troy, NY	RPI	50-225	2003[*]
14.	University of Virginia-Cavalier	Charlottesville, VA	Cavalier	50-396	2002
15.	Manhattan College	Riverdale, NY	MCZPR	50-199	1984
	TRIGA, UZrH Rod Fuel 70% Enriched Uranium				
16.	Oregon State University	Corvallis, OR	OSTR	50-243	2002
17.	Texas A&M University	College Station, TX	NSCR	50-59	2002
18.	University of Wisconsin	Madison, WI	UWNR	50-156	2000
19.	Washington State University	Pullman, WA	WSUR	50-27	2002
	ARGONAUT, Plate Fuel 93% Enriched Uranium				
20.	University of California-Los Angeles	Los Angeles, CA	UCLA-R1	50-142	1980[**]
21.	University of Florida	Gainesville, FL	UFTR	50-83	2002
22.	University of Washington	Seattle, WA	UWNR	50-139	1989
23.	Virginia Polytechnic Institute and State University	Blacksburg, VA	VTAR	50-124	2002
24.	Iowa State University	Ames, IA	UTR-10	50-116	2003[*]
	Atomics International L-77, Aqueous Homogeneous, 90% Enriched Uranium				
25.	University of California-Santa Barbara	Santa Barbara, CA	UCSB	50-433	1994[***]

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[*] License renewal pending. Projected expiration date assuming license is renewed in 1983 or 1984.

[**] In hearing. License renewal date is not specified.

[***] Fuel possession only license.

Table 1.2

University Research and Training Reactors with HEU Fuel

	University/Laboratory	Auth. U-235 Kg	Annual U-235 Requirement (Kg)	Power Level (Mw)	Annual Energy Production (MwD/yr)
	Plate Type Fuel, 93% Enriched Uranium				
	High Power				
1.	University of Missouri-Columbia	45.0	18.7	10	3,250
2.	Massachusetts Inst. of Technology	29.0	5.4	5	1,021
3.	Georgia Inst. of Technology	13.5	1.9*	5	432
	Medium Power				
4.	Rhode Island Nuclear Science Center	10.4	2.5	2	146
5.	University of Michigan	16.1	3.3	2	433
6.	University of Virginia-UVAR	17.6	1.3	2	167
7.	University of Lowell	4.8	0.2	1	21
	Low Power				
8.	University of Missouri-Rolla	4.3	0*	0.2	0.5
9.	Ohio State University	4.6	0*	10^{-2}	<0.1
10.	University of Kansas	4.0	0*	10^{-2}	<0.1
11.	Worcester Polytechnic Institute	4.0	0*	10^{-2}	<0.1
12.	Purdue University	3.0	0*	10^{-3}	<0.1
13.	Rensselaer Polytechnic Institute	4.99	0*	10^{-4}	<0.1
14.	University of Virginia-Cavalier	--	0*	10^{-4}	<0.1
15.	Manhattan College	3.2	0*	10^{-7}	<0.1
	TRIGA, UZrH Rod Fuel 70% Enriched Uranium				
16.	Oregon State University	16.3	0.07*	1	38
17.	Texas A&M University	17.2	0.18	1	104
18.	University of Wisconsin	13.7	0.11*	1	33
19.	Washington State University	19.9	0.04*	1	38
	ARGONAUT, Plate Fuel 93% Enriched Uranium				
20.	University of California-Los Angeles	4.9	0*	0.1	1.3
21.	University of Florida	4.8	0*	0.1	0.9
22.	University of Washington	7.5	0*	0.1	0.4
23.	Virginia Polytechnic Institute and State University	8.0	0*	0.1	2.1
24.	Iowa State University	4.6	0*	10^{-2}	<0.1
	Atomics International L-77, Aqueous Homogeneous, 90% Enriched Uranium				
25.	University of California-Santa Barbara	1.4	0*	10^{-5}	<0.1
	Totals	262.79	33.7	31.6	5688

*Lifetime cores

The University of Michigan demonstration of conversion was relatively simple in that no changes to the reactor thermal-hydraulics parameters or to the reactor configuration were required. Moreover, this work was heavily supported by DOE funds ($460,000 over five years, exclusive of fuel). Because this case may be atypical it was advisable to gather information from the university reactors concerning particular problems expected in conversion to LEU. The inquiry letter and the results of this LEU Conversion Survey are included here as Appendix A.

The RERTR program has involved detailed numerical computations of LEU conversion for international benchmark reactors[5]. Detailed numerical computations of LEU conversions have not been carried out for particular U.S. university research reactors in most cases. Such detailed numerical computations were not included in the time frame and scope of the LEU Study Group. In this report of the LEU Study Group there appear certain reservations dependent on the outcome of detailed computations.

The information developed in this study, in conjunction with information from other sources, will be taken into account by the NRC in rule making proceedings for amending the operating licenses of converted domestic research reactors. The technical, economic, and operating data base assembled in this study, and the proposed NRC rules and guidelines, will be available to interested foreign research reactor operators and their regulatory agencies for possible consideration in connection with their own conversion licensing activities.

1.3 LEU Conversion

For some university reactors, such as the University of Michigan reactor, conversion from HEU fuel to LEU fuel is a straightforward substitution of one fuel type for another, leaving the thermal-hydraulics properties and most safety aspects unchanged (see Sections 2 and 4). In such cases, the functional capabilities of the reactors may be only slightly altered as well. For the University of Michigan reactor, the costs of conversion were large, about three-quarters of a million dollars including fuel, three man-years of effort, and six calendar years (see Sections 3 and 5). If generic licensing and other economies of scale are applied to the other reactors of this class, the cost is still estimated to be large by university standards (see Section 3). The four medium power and possibly the four TRIGA reactors listed in Table 1.1 are in this class.

Another class of university reactors would require substantial modification in order to convert from HEU to LEU fuel. Even for low-power training reactors of this class the costs of conversion are not likely to be much less than those cited above.

The MIT and University of Missouri-Columbia reactors would require advanced fuel development for conversion without substantial loss of capability (see Section 2). With the exception of these two reactors the university reactors now using HEU fuel can be converted to LEU fuel, but at costs which are substantial and possibly prohibitive by university standards. Thus, the LEU Study Group emphasized cost/benefits as well as technical aspects of LEU conversion.

It appears that the U.S. has lost, or is losing, its preeminence in the field of neutron studies of condensed matter and other disciplines utilizing research and test reactor capability. The national interest may require enhancement of this capability at some universities together with increased research support and the continued use of HEU fuel so that the U.S. maintains a desired position in these important research areas.

2. Technical Feasibility

2.1 Introduction

A preliminary assessment has been made of the technical feasibility of converting 25 university reactors from HEU to LEU fuel. Such reactor parameters as power, fuel plate and element geometry, uranium density, and thickness of the fuel meat affect feasibility. Other reactor features, such as the reactor control and cooling systems, must also be considered in assessment of feasibility.

2.2 Definition of Technical Feasibility

Technical feasibility, for the purposes of this document, is defined by Section 1.4.1 of IAEA-TECDOC-233[8], which states: "In assessing the practical feasibility of utilizing lower enriched fuel in existing research reactors, the agreed criteria are that safety margins and fuel reliability should not be lower than for the current design based on highly enriched uranium, major reactor modifications should not be required, and that preferably neither any loss in the overall reactor performance (e.g. flux-per-unit power) nor any increase in operation costs should be more than marginal." The cited International Atomic Energy Agency document was prepared by a consultants' group that included representatives of the Argonne National Laboratory Reduced Enrichment Research and Test Reactor (RERTR) Program.

Because of the wide ranges in reactor power levels and applications, it is difficult to assign precise values to the above criteria, but the research reactor community would probably regard any modification cost approaching even one percent of the reactor capital cost as major, and any loss in performance or increase in operating costs in excess of 5-10% as more than marginal. These estimates will vary substantially from one facility to another, depending upon economic constraints and the purposes for which the reactor is used. The LEU survey responses attached as Appendix A indicate that some universities are unable to absorb any substantial costs that may result from a required conversion to LEU. Some facilities have gone to considerable effort and expense to optimize reactor designs, such as the University of Missouri-Columbia's central thermal flux trap for producing high specific activity radioisotopes. Others have optimized existing experiment facilities, such as the University of Michigan's heavy water reflector tank for maximizing neutron beam port fluxes. Any reduction in performance negates a fraction, perhaps a substantial fraction, of improvements achieved. Conversion to LEU might require reoptimization of such facilities with possible reductions in performance.

2.3 Reactor Characteristics Related to Feasibility

Designers of university research, test and training reactors must consider many technical factors, weigh their importances, and strike a proper balance depending on the objectives for the facility. Some reactors are designed for multiple purposes, for example, for research and for training in nuclear principles and reactor operation. Training facilities emphasize ease of operation, access to the reactor and similarity to power reactors. Those intended for research purposes must emphasize the highest feasible neutron fluxes in beam ports and in irradiation facilities. The former are required or studies of condensed matter and the latter for investigations of radiation effects. Capital costs and economy in operation are essential considerations in all cases. Safety is paramount and the complexity of safety systems and engineered safeguards reflect the size and type of reactor.

Where maximum neutron fluxes for high level research are the primary objective, as for the University of Missouri-Columbia and MIT reactors, the reactors were carefully designed, and the total reactor power was made as high as possible consistent with economic restrictions, cooling systems, shielding, containment, with NRC distinctions between research and test reactors (e.g. 10 MW power distinction), and with other factors.

Within these limits, maximum fluxes are obtained by making the power density as high as possible. This implies a minimum core volume for a given power, but it still must be sufficiently large to serve experimental facilities and to contain enough fissile material for adequate excess reactivity at end-of-cycle. For a given power, and hence a given burnup rate, the fissile loading should be high, so that the fuel will last as long as possible to minimize fuel cycle costs, refueling time, radiation exposures, and transportation hazards. A high total loading could be accomplished by increasing the core size, but for a given total reactor power, the power density must then be decreased, contrary to design intentions. Accordingly, the maximum amount of fissile material must be contained in a small core volume. Within this core volume, there must still be space for the passage of adequate amounts of coolant as well as sufficient transfer surface to remove the heat generated.

For high performance reactors, these objectives can best be met with fuel containing the maximum concentration of uranium-235 (the only feasible fissile material), which has been accomplished historically by using HEU at the highest uranium concentration found practicable to date, about 1.6 grams total U/cc. The RERTR program hopes to demonstrate higher uranium concentrations (using LEU) over the next year or two. The fuel is contained in thin aluminum plates, typically 0.050 -0.060" thick, to maximize the heat transfer surface area. The MIT reactor fuel in addition has small fins machined into the plate surface to further increase the area.

Conversion from HEU to LEU can be regarded as increasing the amount of U-238 from a fraction 0.07 relative to the U-235 at 93% enrichment to a fraction of 4 at 20% enrichment; the increase is by a factor of 57. The accompanying buildup of fissile plutonium is not very important from a reactivity point of view, and its radiological effects are small compared with fission products. The essential effect of LEU conversion is to add a strong long-lived poison, U-238, to the fuel. More U-235 must be added to the fuel in order to compensate for this poison and still achieve reasonable excess reactivity and cycle times. More U-238 must then be added in order to maintain the U-235 at less than 20%, and so on until satisfactory design is achieved. The result is that the fuel must have a high uranium density, about five and one-half times that which would be required for HEU.

For many of the university reactors, unlike for MIT and Missouri-Columbia, it is feasible to achieve this denisty by increasing either the uranium density in the fuel meat or the thickness of the fuel meat in th plates, or both. In some cases the latter can be accomplished only at the expense of decreasing the coolant channel thickness. This then requires re-analysis of the thermal hydraulic performance of the core and, possibly, modifications to the cooling system.

2.4 University Reactor Characteristics Related to Feasibility

There is a great range in the characteristics of university research reactors presently using HEU fuels. Certain features of the 25 NRC-licensed university reactors are given in Table 2.1. It is seen that power levels range from 0.1 watts to 10,000,000 watts, that uranium densities in the core "meat" of fuel plates vary from 0.25 g U/cc to 1.6 g U/cc, and that there are several types of materials used for fuel and for control purposes.

There are technical limitations on converting from HEU to LEU if the latter is to be accommodated in the fuel plates or rods without any change in fuel plate geometry. If there is no change in fuel plate outer dimensions, the operating and transient thermal-hydraulic characteristics are changed little, if at all, and so no major modifications should be required, other than in the fuel. It would be necessary to revise the Safety Analysis Report, showing that control worths are adequate, etc., but the revisions would be minor (See Section 4). In order to convert from HEU to LEU fuel and maintain the same fuel plate outer dimensions, the uranium density can be increased in the fuel meat.

An alternative to increasing uranium density is to change fuel plate geometry, for example to increase fuel meat thickness. This could result in significant changes in core fluid flow and heat transfer characteristics if the plates must also be made thicker. Alternatives that produce core thermal-hydraulic modification are undesirable because they increase the scope of the facility's license change from a minor amendment to a major revision and because of potential expenses associated with engineering modifications to the facility.

Uranium density limits on current fuel meat technology that have been proven and operationally tested in research reactor fuels are given in Table 2.2.

Test programs sponsored by the Department of Energy through Argonne National Laboratory are designed to demonstrate by the dates indicated that uranium densities can be increased to the values also listed in Table 2.2 for the various types of fuels. The values are taken from information provided by the RERTR Program.

Table 2.1

Reactor Parameters

Reactor	Power (MW)	No. of Elements Norm/Max	Element U-235 (grams)	No. of Plates	Plate Thick. (mils)	Clad/Core /clad (mils)	Control Poison
Plate-Type Fuel - 93% Enriched							
High Power							
1. Missouri-Columbia	10	8/8	780	24	50	15/20/15	Boral
2. MIT	5	24/27	510	15	70 av.	20/30/20 av	B-SS
3. Georgia Tech	5	17/19	190	16	50	15/20/15	Cd
Medium Power							
4. Rhode Island	2	30/35	120	18	60	24/12/24	Boral
5. Michigan	2	35/45	167	18	50	15/20/15	B-SS
6. Virginia-UVAR	2	20/64	190	18	50	15/20/15	B-SS
7. Lowell	1	26/30	140	18	60	24/12/24	Boral
Low Power							
8. Missouri-Rolla	0.2	27/51	170	10	60	20/20/20	B-SS
9. Ohio State	0.01	24/30	140	10	108	36/36/36	B-SS
10. Kansas	0.01	16/20	170	10	60	20/20/20	Boral
11. WPI	0.01	25/51	140	10	99	30/40/30	Boral
12. Purdue	0.001	-	170	10	100	20/60/20	-
13. RPI	0.0001	25/49	-	-	30	5/20/5	-
14. Va.-Cavalier	0.0001	-	165	12	50	15/20/15	-
15. Manhattan	10^{-7}	18/31	-	-	-	15/--/15	Cd, SS
TRIGA UZ_rH Fuel 70% w/o Enriched							
16. Oregon State	1	89/126	126	n.a.	1.47 D	1.43/.020	B-graphite
17. Texas A&M	1	90/202	122	n.a.	1.41 D	1.37/.020	B-graphite
18. Wisconsin	1	91/236	122	n.a.	1.41 D	1.37/.020	Boral
19. Wash. State	1	110/196	122	n.a.	1.41 D	1.37/.020	Boral
Argonaut H_2O & Graphite 93 w/o enriched							
20. U. Cal. - LA	0.1	24/24	140	11	70	15/40/15	Cd
21. Florida	0.1	24/24	140	11	70	15/40/15	Cd
22. U. Washington	0.1	24/24	143	11	70	15/40/15	Cd
23. VPI	0.1	12/12	266	12	80	20/40/20	Boral
24. Iowa State	0.1	12/12	266	12	80	20/40/20	Boral
Aqueous Homogeneous							
25. U. Cal. - SB	10^{-5}	Aqueous solution, 1.3 ft. diameter sphere					Cd

Table 2.2 Current and Planned Fuel Technology

Fuel Meat	Clad	Uranium Density in Fuel Meat (g/cc) Current	Uranium Density in Fuel Meat (g/cc) Planned	Planned Qualification Dates
UAl_x-Al	Al	1.60	2.3	January 1984
U_3O_8-Al	Al	1.30	3.2	June 1985
$UZrH_x$	Stainless Steel	0.35	3.7	January 1985
U_3Si_2-Al	Al		4.8	January 1986
U_3Si-Al	Al		7.0	June 1989

The increase in uranium density necessitated by conversion from 93% HEU to LEU fuel can be fairly accurately calculated as follows:

$$\begin{aligned} \text{Uranium Density}\Big|_{\text{LEU}} &= \text{Uranium Density}\Big|_{\text{HEU}} \quad \text{(g/cc)} \\ &\quad \text{X } 0.93 \text{ (g U235/g U in HEU)} \\ &\quad \text{X } 5 \text{ (g U/g U235 in LEU)} \\ &\quad \text{X } 1.15 \\ &= 5.35 \text{ Uranium Density}\Big|_{\text{HEU}} \qquad (2.1) \end{aligned}$$

The factor, 1.15, accounts for extra uranium 235 necessary in LEU fuel to overcome increased uranium 238 resonance absorption and produces approximately the same end-of-cycle core reactivity as existed with HEU fuel.

For TRIGA reactors with 70% rather than 93% enriched fuel, the uranium density is approximately:

$$\text{Uranium Density}\Big|_{\text{LEU}} = 4.03 \text{ Uranium Density}\Big|_{\text{HEU}} \qquad (2.2)$$

Using equations (2.1) and (2.2), LEU uranium densities have been calculated for the 25 universities being considered. The values are listed in Table 2.3 along with the fuel type proposed for use by each reactor assuming direct LEU substitution for HEU with no plate or element dimension changes.

2.5 Reactors for which LEU Conversion is Technically Feasible

It is instructive to consider reactors using the extremes in uranium loading (refer to Table 2.3). Purdue at 0.25 g U/cc, WPI at 0.35 g U/cc, Ohio State at 0.41 gU/cc, and Michigan at 0.33 g U/cc have the lowest HEU loadings. The last reactor has been converted to LEU fuel with no technical problems, because it was possible to utilize a current state-of-the-art fuel technology, UAl_x with a density of 1.6 g U/cc, plus a thicker plate to accommodate the necessary extra uranium (0.060 in., a thickness previously used for Michigan fuel and, hence, easily licensed).

Table 2.3 Estimate of Core Changes Required to Use LEU

			If No Dimensional Changes			If Present Fuel Technology[1,2,3] Must Change Parameter, From/To			
Reactor	Power (MW)	Present Density (g U/cc)	Required Density (g U/cc)	Fuel Tech Req'd	Date Qualified	Fuel Meat (mils)	Plate (mils)	No of Plates	No of Elmnts
Plate-Type Fuel - 93% Enriched									
High Power									
1. Missouri-Columbia	10	1.6	8.6	-	1989+		Not Feasible		
2. MIT	5	1.6	8.6	-	1989+		Not Feasible		
3. Georgia Tech	5	0.66	3.5	U_3Si_2	1986	20/39[4]	50/69	n.c.*	17/19
Medium Power									
4. Rhode Island	2	0.72	3.9	U_3Si_2	1986	12/30	n.c.	n.c.	n.c.
5. Michigan	2	0.33	1.8	UAl_x	1984	20/30	50/60	n.c.	n.c.
6. Virginia-UVAR	2	0.61	3.3	U_3Si_2	1986	20/30	50/60	n.c.	20/28
7. Lowell	1	0.78	4.2	U_3Si_2	1986	12/30	n.c.	n.c.	26/27
Low Power									
8. Missouri-Rolla	0.2	0.94	5.0	U_3Si_2	1986	20/33[4]	n.c.	n.c.	27/51
9. Ohio State	0.01	0.41	2.2	$U\ Al_x$	1984	36/50	n.c.	n.c.	n.c.
10. Kansas	0.01	1.03	5.5	U_3Si	1989	20/30	n.c.	10/18	16/20
11. WPI	0.01	0.35	1.9	$U\ Al_x$	1984	40/47	n.c.	n.c.	n.c.
12. Purdue	0.001	0.25	1.3	$U\ Al_x$	now	n.c.	n.c.	n.c.	n.c.
13. RPI	0.0001		Redesign						
14. Va.-Cavalier	0.0001	0.61	3.3	U_3Si_2	1986	20/30	50/60	n.c.	-
15. Manhattan	10^{-7}	-	-	-	-	-	-	-	-
TRIGA UZ$_r$H Fuel - 70% w/o Enriched									
16. Oregon State	1	0.47	1.9	UZrH	1985	No changes, but short core life			
17. Texas A&M	1	0.49	2.0	UZrH	1985	No changes, but short core life			
18. Wisconsin	1	0.46	1.9	UZrH	1985	No changes, but short core life			
19. Wash. State	1	0.50	2.0	UZrH	1985	No changes, but short core life			

Table 2.3 Estimate of Core Changes Required to Use LEU (Continued)

			If No Dimensional Changes			If Present Fuel Technology[1,2,3] Must Change Parameter, From/To			
Reactor	Power (MW)	Present Density (g U/cc)	Required Density (g U/cc)	Fuel Tech Req'd	Date Qual-ified	Fuel Meat (mils)	Plate (mils)	No of Plates	No of Elmnts
Plate-Type Fuel - 93% Enriched									
Argonaut - H_2O & Graphite - 93 w/o Enriched									
20. U. Cal. - LA	0.1	0.44	2.4	UAl_x	1984	40/60	70/90	n.c.	n.c.*
21. Florida	0.1	0.38	2.0	UAl_x	1984	40/51	70/81	n.c.	n.c.
22. U. Washington	0.1	0.45	2.4	UAl_x	1984	40/60	70/90	n.c.	n.c.
23. VPI	0.1	0.58	3.1	U_3O_8	1985	40/70	80/100	12/14	n.c.
24. Iowa State	0.01	0.58	3.1	U_3O_8	1985	40/70	80/100	12/14	n.c.
Aqueous Homogenous									
25. U. Cal. - SB	10^{-5}	0.044	0.24	Now Higher Concentration		-	-	-	-

Notes:

(1) Present technology means 1.6 g U/cc for UAl_x; 0.35 for UZrH.

(2) Increasing plate thickness or number of plates may cause significant change in hydraulics.

(3) Increasing number of elements means larger core, hence lower fluxes, which may fail to meet criterion of no penalty in performance.

(4) Plates with cores thicker than 30 mils may not be considered qualified for use in these reactors.

* n.c. means no change

It appears that Purdue's 0.25 g U/cc for HEU could be converted to about 1.34 g U/cc for LEU without any geometry change. WPI's 0.35 g U/cc for HEU would require 1.87 g U/cc for LEU (expected to be demonstrated by 1984) or the existing 1.6 g U/cc if the clad-meat-clad in mils dimensions are changed from 30/40/30 to 26.5/47/26.5. Ohio State's 0.41 gU/cc for HEU would require 2.2 gU/cc for LEU or the existing 1.6 gU/cc if the clad-meat-clad dimensions are changed from 36/36/36 to 29/50/29. Presumably there will be no licensing problems for 1 KW and 10 KW reactors changing to LEU in 0.100 in. thick plates having fuel meat cores of these projected thicknesses.

The University of California-Santa Barbara has a uranyl sulfate solution reactor. The potential for increasing density in this aqueous homogeneous core is presumed to be possible since a similar reactor at Brigham Young University is now operating with 20% enriched uranium.

2.6 Reactors for which LEU Conversion Is Not Technically Feasible

At the other extreme are Missouri-Columbia and MIT. Both of these reactors have been designed to operate with HEU at a density of 1.6 g U/cc, the highest loading that has been demonstrated for plate-type fuel to date, although it is expected that somewhat higher loadings will be proven by the RERTR Program within the next year or so. Information furnished by the program, indicates that densities of 2.3 g U/cc should be qualified in FY 1984 (UAl_x), and 3.2 g U/cc in FY 1985 (U_3O_8). The highest loading that RERTR currently is planning to investigate is 7.0 g U/cc, using the new, still unproven U_3Si technology, the qualification date for which RERTR estimates to be about 1989. This loading is still less than the 8.6 g U/cc density that it is estimated will be necessary for Missouri-Columbia and MIT if these reactors are to convert to LEU with no change in the fuel geometry.

The Missouri and MIT core designs provide practically no flexibility for changing the core geometry, e.g. increasing the core size, to accommodate more uranium. Both cores are contained in structures that cannot be expanded without major modifications, a requirement that IAEA did not contemplate as being technically feasible. The fuel meat in the MIT design is already 0.030 in. thick, and the fuel plate surfaces are finned to increase the heat transfer by a factor of almost two. Missouri already uses a high primary coolant velocity, 23 ft/sec, so that thicker plates and narrower channels would quickly lead to excessive pressure drops across the core. Only minimal increases in element loadings could be achieved by geometry changes in the fuel itself, and even for these increases detailed thermal-hydraulic studies would be required to determine what higher loadings, if any, are possible.

2.7 Reactors for Which LEU Conversion May Be Technically Feasible After Further Study

In between the above extremes are 18 reactors with varying characteristics. The Rhode Island (2 MW) and Lowell (1 MW) reactors have characteristics that may minimize the impact of conversion relative to other reactors. Specifically, the clad-core-clad dimensions are 24-12-24 mils, respectively, suggesting that a 1.6 g U/cc density in a 15-30-15 mil plate might permit LEU fuel to be fabricated with current technology and no overall plate or element dimensional changes. In these, as in other reactors, it will be necessary to demonstrate that safety is not compromised, (e.g. control blade worths are adequate, power excursions will be limited prior to core damage, etc).

The University of Virginia-UVAR Reactor (2 MW) uses 20 mil meat in its fuel, and hence cannot gain as much by going to 30 mils. It appears that a larger core (more elements) is possible; one-third larger would appear to be required, but this would decrease the flux in inverse proportion, in addition to the decrease that would result directly from the LEU conversion. This does not meet the criterion of no penalty in performance, and so it would be necessary to await the development of U_3Si_2 fuel, estimated by RERTR for FY 1986, or to investigate the effects on other parameters of approximately doubling the core fuel meat thickness. In all of these cases it is understood that the estimates are only approximate and that detailed analyses are necessary to predict the expected change.

Georgia Institute of Technology, the only other plate-type reactor in the megawatt range, appears to be more restricted in that the core size can be only slightly increased, from 17 to 19 elements.

At the University of Missouri-Rolla (0.2 MW), the situation is similar to that at Virginia, with the added option of increasing the number of plates above 10 per element.

All of the last three reactors above probably can convert to LEU without any geometry change when the U_3Si_2 fuel is demonstrated at 4.8 g U/cc, estimated by the RERTR program for FY 1986.

There are seven reactors in the "Low Power" category, with power levels up to 10 KW. These are among the facilities with life-time cores. There is only limited information available in Reference 4, but it appears technically feasible for Purdue, Ohio State, and WPI to convert, as mentioned earlier. On the other hand, the University of Kansas reactor uses HEU at 1.03 g U/cc and will have to await the demonstration of U_3Si (about FY 1989) unless the core meat thickness, the number of plates and the number of elements are all increased.

The class of reactors known as ARGONAUTS, four reactors at 100 KW and one at 10 KW, have relatively low density HEU fuel, 0.38 - 0.58 g U/cc, and probably can be converted to LEU when the 2.3 g U/cc UAl_x is qualified, estimated to be in FY 1984. Conversion with today's technology may be feasible if increasing the number of plates per element above 11 and decreasing the water gap is possible. This, presumably, would increase the depth of analysis required in the SAR.

TRIGA reactor groups have found from experience that 70% enriched fuel provides a longer fuel life in the core than 20% enriched fuel and, hence, reversion to the lower enrichment will increase fuel cycle costs. However, it appears that conversion to LEU without economic penalty may be possible following the demonstration of higher $UZrH_x$ fuels, expected by RERTR for FY 1985.

2.8 Conclusion

Based on our assessment, conversions can be divided into three categories: those that appear to be technically feasible with today's fuel technology, those that are not feasible even with advanced technologies now under development or projected, and those that require further study before a prediction of technical feasibility can be made with confidence. The reactors at Michigan (already demonstrated), Purdue, WPI, and Ohio State University pool reactors which now have fuels with the lowest uranium densities, fall in the first category, along with the liquid fueled reactor at UCSB. Missouri-Columbia and MIT, with the highest uranium densities, fall in the second, and all other reactors are in the third category pending further evaluation.

2.9 An Alternative to LEU for Proliferation Reduction

In addition to the fuel development work under the direction of the RERTR Program, EG & G -Idaho is overseeing an Extended Life Aluminide Fuels (ELAF) testing program on the Advanced Test Reactor. In this study, mini-plates having UAl_3 and UAl_2 aluminides (93% U-235) loaded to concentrations of about 3 g U/cc are being exposed to burnups as high as 3×10^{21} fissions/cc, nearly double the presently allowed burnup. Test results and evaluation should be available in 1984. It is intended that this program will provide a basis for the licensing of high performance reactors such as Missouri and MIT to use such fuels. The advantages would be much longer fuel lifetime, nearly double, with the potential for still greater lifetime if RERTR advanced technologies are applied, (e.g. uranium silicide fuels). Proliferation risks would be reduced as a result of the reduction in shipments of both fresh and irradiated fuels. An additional benefit would be the reduction in fuel handling and hence in radiation exposures.

2.10 Recommendations

The LEU Study Group recommends that the cost of returning unused or partially used HEU fuel be carefully considered in the course of rule working. An economic penalty on the order of $10,000 -$20,000 per fuel element would result if a new regulation would prohibit the use of such unused fuel either in storage at the reactor site or at another location.

It is recommended that consideration be given to the significant savings in direct and indirect costs if conversion to LEU were not to be required until a suitable type of advanced fuel has been demonstrated and becomes available. A desirable advanced fuel will enable a reactor to convert to LEU either by direct substitution or by increasing the fuel meat thickness without increasing the total plate thickness. In this case no thermal-hydraulics changes would be required.

Where conversion to LEU is not technically feasible in the near future, the LEU Study Group recommends that consideration be given to reduction of proliferation risk through the use of medium enriched uranium (MEU) fuel and, through decreased HEU traffic by utilizing advanced fuels technology in combination with HEU.

3. Functional Impacts

3.1 Introduction

The functional impacts of conversion of university reactors from HEU fuel to LEU fuel can be considered as direct costs and benefits and as societal costs and benefits. The former can be quantified in some cases, and this is the primary emphasis of the present assessment. The projection of direct costs and benefits are based on the known costs of the FNR demonstration, on the university responses to the LEU Conversion Survey (Appendix A), on discussions with fuel manufacturers, and on other information. Because there is considerable imprecision in the projection of direct costs, no present worth considerations have been applied here. In addition, there is no assignment of the fraction of direct costs to be borne by government or by universities.

Societal costs and benefits from LEU conversion are difficult to quantify but are nevertheless important.

3.2 Direct Costs of LEU Conversion

3.2.1 Fuel Costs

The largest component of direct cost is that for fuel. The fuel in U.S. university reactors has been and presumably will continue to be owned by the DOE, which bears the costs of ore, conversion, enrichment, and disposal. Costs of fabrication are identified through discussions with commercial vendors and may be borne or shared by universities. Fuel shipment costs also are substantial and may be borne by the university in some cases.

It was brought out in the previous Section 2 that for many university reactors the number and form of fuel plates and assemblies would be little changed by LEU conversion. Thus, fabrication charges per core may be similar for LEU fuel and HEU fuel unless, as is discussed later, an unusual fuel type is involved.

Fuel for plate-type reactors and for TRIGA reactors has been manufactured for more then two decades. Thus cost data are available from commerical vendors for both types of fuel. Fuel vendors for plate elements include one domestic firm (Babcock and Wilcox Company) and two foreign firms (NUKEM and CERCA). TRIGA fuel is available from the General Atomic Company. The costs for manufacturing MTR low power plate-type fuel are estimated to be $500 per plate. For the FNR demonstration core the cost per fuel plate was approximately $450 and the total core cost was $320,000 for a 40 element core. Immediate conversion to LEU fuel elements would result in extra costs to the licensee because the existing inventory of HEU fuel must be shipped to a receiver designated by the DOE. The costs of HEU fuel shipments from FNR are expected to be about $50,000.

LEU fuel requires about 5.5 times as much uranium as does HEU fuel (see Section 2), but the feed-to-product ratio and the separative work requirements per kilogram of product are about five times less, so that total costs of ore, conversion, and enrichment are about the same. Thus, total fuel costs are expected to be about the same for a fresh LEU core and a fresh HEU core. The modest buildup of fissile plutonium in an LEU core can extend the cycle time slightly, but this depends on the actual operating strategy adopted and in any case is a small effect.

A significant cost increment could arise if a high power university research reactor were required to convert to an LEU fuel with an inadequate uranium density (see section 2). In this case, the reduced initial reactivity of each fuel assembly would result in a shorter cycle time and an increased number of assemblies loaded per year. The resulting cost increment would be largely from fabrication, transportation, and disposal of the additional fuel assemblies. Because the cycle time between refuelings already is short (of the order of a week or a month) for high power research reactors, any reduction in cycle time probably would result in higher operational costs as well.

Here it is useful to distinguish several conversion options, A, B, and C. If the HEU fuel already produced for university reactors were to be consumed and replaced by LEU fuel at refueling time (Option A) then the incremental costs of conversion to LEU fuel would be small, because as was noted above an LEU fuel assembly or an LEU core costs about the same as for HEU fuel. It is assumed under Option A that the MIT and University of Missouri-Columbia high power research reactors would not be required to convert to LEU fuel because this is not foreseen to be technically feasible (Section 2). Thus Option A has little additional direct cost for fuel and transportation, although there are substantial administrative, analysis, and other costs (see Section 3.2.2).

Option B is the same as Option A except that incore HEU fuel is replaced at time of normal refueling by LEU fuel as rapidly as this can be delivered (see Section 5, scheduling), and unused HEU (on-site and off-site) fuel is returned to DOE for disposal. About 100 HEU fuel elements for university reactors might be scrapped under Option B, at a cost of about one million dollars. Only fabrication and transportation costs are included here, because other fuel values are not lost.

Option C assumes that all university reactors, except MIT and University of Missouri-Columbia, are required to replace HEU fuel with LEU fuel as rapidly as LEU fuel can be delivered. Reactors with lifetime cores thus would be converted to LEU under this option. The cost of fuel fabrication and transportation for this option is estimated to be about nine million dollars.

3.2.2 Other Costs

For most of the reactors in Table 1.1, given advanced fuel technology, LEU fuel can be fabricated having the same dimensions as existing HEU fuel. In this case, the thermal-hydraulic characteristics of the reactor are not affected by the conversion and no modifications to the reactor cooling system are needed. For the FNR costs under this category were zero. Other engineering modifications might be required, such as relocation of control rods or detectors. Administrative, analysis, and other costs based on those for the FNR demonstration are shown in Table 3.1. These costs include neither the cost of fuel fabrication nor the cost of HEU shipment. Specific costs for an Argonaut reactor are shown in Table 3.2.

For some reactors, such as Manhattan College, fuel redesign may be required. For all reactors there are administrative costs associated with changes in fuel procurement, development of new operational strategies including set points, retraining, and reoptimization of experimental locations.

A very significant cost associated with conversion to LEU is for revisions of the Safety Analysis Report (SAR) and of the Technical Specifications, and for application for and defense of an amendment to the facility license (Section 4). Most reactors produce research and educational services which generate income

Table 3.1 Administrative and Analysis
Costs Based on Those for the FNR Demonstration Conversion

Task	Man Hours	Cost (@ $40/Man Hr)
Program Planning	120	$ 4,800
Safety Analysis and License Amendment	600	24,000
Core Physics Calculations	4,000	160,000
Thermal Hydraulics Calculations	600	24,000
Engineering Modifications	200	8,000
LEU Fuel Specifications	200	8,000
Staff Training	80	3,200
HEU Fuel Transfer	80	3,200
LEU Core Testing	320	12,800
TOTAL		$248,000

Table 3.2

Costs for LEU Conversion for an Argonaut Reactor (VTAR)

Preparation and Defense of Safety Analysis Report	
6 man months @ $4,000/man month	$ 24,000
Revenue Loss during Conversion	
6 months @ $3,000/month	18,000
Fabrication of LEU Core	
169 plates @ $500/plate	84,500
Hardware, 13 elements @ $300 each	3,900
Shipment of HEU Core	
12 elements @ $5,000/element	60,000
TOTAL	$190,400

to the facility. During the conversion to LEU fuel, the facility would be shut-down for the transition and hence a loss of income would result. A testing program is required after conversion to LEU fuel. This program includes measurements of reactivity coefficients, flux and power distribution and control rod worths. Based on the experience of the FNR the costs incurred for lost services and restart tests are summarized in Table 3.1. Both calculational and experimental work done at the FNR demonstrated that no significant costs were incurred as a result of degradation of core performance with the LEU fuel. The costs itemized in Table 3.1 are less than the actual administrative and analysis costs, which totaled $460,000.

The university responses to the LEU Conversion Survey, together with the FNR demonstration data, suggest that these non-fuel costs total to about $250,000 per reactor. This figure is less than that for the FNR conversion, because it assumes that some reactors of similar type will be able to take advantage of the lead reactor concept and generic licensing. On the other hand, some unique reactors may require substantially larger figures. The total of the non-fuel costs of converting the 23 university reactors other than University of Missouri-Columbia and MIT thus is estimated to be about six million dollars.

3.3 Direct Benefits of LEU Conversion

Only those benefits which might be realized by the reactor licensee are considered in this section. Thus, for example, the small savings in enrichment costs are ignored because they would accrue to a third party (DOE).

Most of the university reactors maintain only a small inventory of Special Nuclear Material (SNM) and qualify either as Category II or III facilities. According to the criteria in 10 CFR 73.67, Category II facilities are licensed to possess between 1 Kg and 5 Kg of non-self-protecting (<100 Rem/hr at 3 feet) U-235 as HEU. Table 1.2 shows those reactors authorized to possess more than 5 kg U-235 as HEU; some of these are protected by high fuel radiation levels. For fuel with 10% to 20% enrichment, Category III facilities can possess between 1Kg and 10Kg of U-235. For some reactors conversion from HEU to LEU might permit a reclassification to a lower category and hence result in cost savings. For the University of Michigan FNR, such cost savings were not possible.

A substantial, but only immediate, benefit of LEU conversion might be the deferral of decommissioning costs. These appear to be speculative for most reactors, judging from the responses to the LEU conversion survey.

3.4 Societal Costs and Benefits

Terrorist activity or nuclear proliferation involving HEU from a university reactor could have major consequences for society in general and for the universities in particular. Thus conversion to LEU, by preventing such events, could provide large potential benefits.

On the other hand, a program of conversion to LEU that required excessive costs to be borne by the universities might result in the shutting down of some of the university reactors. The loss of nuclear training capability could have severe effects on the production of trained personnel for the nuclear discipline. In addition, loss of university research capability could further decrease the U.S. stature in areas such as condensed matter studies. The importance of reactor research on condensed matter has been endorsed by the National Academy of Sciences[10] and by the DOE[11]. The recent International Symposium on the Use and Development of Low and Medium Flux Research Reactors[13] emphasized other significant areas of research as well. A hypothetical transfer of research reactor capability from the universities to DOE laboratories, even with cooperative programs, might have little success because of logistical difficulties and differences in administrative and research environments.

3.5 Conclusions

It is concluded that the technical feasibility of LEU conversion can be established for most university reactors (See Section 2). However, in terms of a cost-benefit analysis, the major benefit that would accrue is the reduction in the risk of unauthorized diversion of HEU. This is an intangible benefit that cannot be quantified. Direct costs, on the other hand, can be assessed to some extent and are large by university standards.

Excessive application of these LEU conversion costs to university reactors may result in the shutting down of some of these.

3.6 Recommendations

It is the primary recommendation of this study that, if conversion to LEU fuel is mandated by the NRC, then adequate funding for this conversion must be provided by the federal government. Otherwise, many university-based reactors may have to be shutdown. It is recommended that the NRC encourage the provision of federal funds for all aspects of LEU conversion: analysis, facility modifications, new fuel, startup tests with new fuel, and spent fuel shipment.

It is recommended that the NRC establish a priority system for LEU conversion. The factors that would affect this priority list include: (1) LEU fuel availability and cost; (2) fuel consumption; (3) fuel cycle costs (fabrication, shipping, reprocessing). It is recommended that the highest priority for LEU conversion should be for plate-type reactors having 0.2Mw<Power<2 Mw, since the fuel technology is reasonably assured, and this group comprises a significant fraction of all university reactors. The second priority should comprise the remaining low power reactors. The third priority should be for reactors with Power > 2Mw and with high power density. This group comprises only 2 reactors for which LEU fuel is not currently available and the costs of conversion will be much higher than for the lower power group.

A recommendation that would offer substantial cost savings is that lead reactors be identified for each group of similar reactors. These reactor staffs would develop SAR's and related documentation which could be used by the other reactor staffs as guides for generic licensing.

4. Licensing

4.1 Introduction

License modifications are required for conversion of university reactors to LEU fuel. The university applications for license modifications and the NRC responses to these require effort, time, and cost. These effort, time and cost requirements are part of the cost/benefit and scheduling considerations which are considered in Sections 3 and 5. No basic problems in licensing are anticipated because the conversion from HEU fuel to LEU fuel appears to have little effect on reactor safety; this is assessed in Section 4.4. No respondee to the LEU Conversion Survey (App. A) anticipated licensing difficulties other than effort, time, and cost requirements. Nevertheless, it is possible, though we consider it to be unlikely, that detailed analyses may reveal LEU-related safety problems for one or more reactors.

The process of LEU license amendment may in certain cases be exposed to intervenor action, and this could have major impacts through delays and costs. The UCLA reactor has been in the public hearing process since September, 1980 and to this date the university has expended about $500,000 on the hearings.

The license docket number and license status for each of the 25 university reactors which are potentially subject to LEU conversion are listed in Table 1.1.

4.2 Licensing Requirements

In the event of LEU conversion the reactor licensee would submit a modified Safety Analysis Report (SAR) as well as a proposed license amendment. Modifications also may be required in the accompanying Technical Specifications and Bases. Full documentation of the proposed nuclear and thermal-hydraulics characteristics for LEU fuel would be submitted to the NRC. Various accident situations would be considered. If the reactor's thermal-hydraulics and control characteristics are demonstrated to be essentially unchanged so that hypothetical accident considerations also are unchanged, then a major SAR revision may be unnecessary.

License amendments, if approved, could be issued in accordance with normal licensing procedures. For the purposes of this report we will distinguish between major and minor license revisions; the former may correspond to those requiring a major SAR revision and, possibly, a new construction permit. If the new fuel requires new and different control systems then a new construction permit may be required. Public hearings might be required if a major license revision is involved. No public hearings would be required for a minor license amendment, which for present purposes is defined as a license revision that is not major.

Some LEU conversion could be accomplished by changing fuel plate composition, leaving the fuel plate outer dimensions and the reactor configuration unchanged. In this case the reactor thermal-hydraulics properties would be virtually unchanged. If shutdown margin and other safety-related characteristics also are satisfactory then the license amendment can be considered to be minor. In Table 4.1 are listed the

Table 4.1 Licensing Categories for LEU Conversion of University Reactors

	Lifetime Core		Routine Fuel Cycle	
LEU CONVERSION	Minor License Amendment	Major License Revision	Minor License Amendment	Major License Revision
With Existing Fuel Technology ($UA\ell_x$ < 1.6gU/cc, $UzrH_x$ < 0.35gU/cc)	Ohio State U. U.C. Santa Barbara Purdue Univ. WPI	VPI* U. of Virginia Cavalier Georgia Tech* Iowa State* Manhattan* UCLA* U. Florida* U. Kansas* U. Missouri-Rolla* U. Washington* RPI* Oregon State U. U. Wisconsin Wash. State U.	U. Lowell U. Michigan Rhode Island	U. Virginia-UVAR Texas A&M
With Anticipated Advanced Fuel Technology (U_3 Si < 7 gU/cc $UZrH_x$ < 3.7gU/cc)	VPI* Georgia Tech* Iowa State* Manhattan* UCLA* U. Flordia* U. Kansas* U. Missouri-Rolla* U. of Washington* RPI* U. Virginia Cavalier Oregon State Univ. U. Wisconsin Wash State U.		U. Virginia-UVAR Texas A&M	U. Missouri-Columbia* MIT*

* Assuming that safety considerations are demonstrated for LEU fuel after detailed analysis of safety parameters and hypothetical accidents.

prospective licensing categories for the 25 university reactors potentially affected by LEU conversion. With existing fuel technology (UAl_x < 1.6 gU/cc, $UZrH_x$ < 0.35 gU/cc) 7 reactors can be converted by LEU fuel substitution with no change in thermal-hydraulics properties; hence minor license amendments are anticipated for these. Another 16 reactors appear to require major license revisions. For the other two reactors, MIT and University of Missouri-Columbia, existing fuel technology is not adequate if loss of performance is not to occur. With anticipated advanced fuel technology (U_3 Si < 7 gU/cc, $UZrH_x$ < 3.7g U/cc) 16 of these reactors can be converted to LEU without change in core thermal-hydraulics. At that point only the University of Missouri-Columbia and MIT reactors would require major license revision.

For several very low power reactors such as RPI and Manhattan College, conversion to LEU fuel may involve considerable modifications to the reactor. These modifications are not expected to reduce safety, but detailed analyses are required to verify this.

4.3 Licensing Status

The NRC licenses 51 university research and training reactors at the present time including those using LEU. No new university applications for license are pending and none are anticipated. A number of original licenses are expiring, however, so that there is a present backlog of university license renewals (See Table 1.1). There are 25 university reactors that use highly enriched uranium; of these five licenses have expired and in each case license renewals have been applied for and are pending.

4.4 Safety Analyses

Safety Analysis Reports require (among other matters) (a) determination of safety-related parameters such as reactivity coefficients, neutron lifetime, excess reactivity, control rod worths, and transient thermal-hydraulic characteristics; (b) consideration of hypothetical accident events; and (c) analyses of hypothetical accident events by use of qualified computer programs. Probabilistic risk assessment is not usually applied; instead attention is focused on identifying and analyzing a maximum hypothetical event. Requirements (a), (b), and (c) are assessed here in turn.

Conversion from HEU fuel to LEU fuel involves adding a long-lasting poison, U-238, to the fuel. This has the effect of hardening the neutron spectrum, so that neutron lifetime and control rod worths are expected to decrease. The U-238 provides a prompt negative Doppler coefficient of reactivity. As a result of the harder neutron spectrum, LEU fuel has a somewhat larger void coefficient of reactivity, but the water temperature coefficient does not change appreciably as a result of conversion by LEU fuel substitution[13]. The buildup of fissile plutonium from neutron capture in the U-238 is, of course, negligible in the low-power university reactors. In the high-power reactors the buildup of fissile plutonium (to perhaps 10% of total fissile at 50% burnup of U-235 in LEU) can reduce the effective delayed neutron fraction by a few percent, and it can reduce the slope of the no-control reactivity versus exposure curve[13]. The latter effect may be used to reduce the excess reactivity at beginning-of-cycle, but other fuel management strategies may be used that do not result in a decrease in excess reactivity. Finally, the higher uranium loading in LEU fuel appears to entail a lower thermal conductivity for the fuel, so that the thermal relaxation time for the fuel is increased.

Turning next to consideration of hypothetical accidents, these are of the same types for LEU fuel as for HEU fuel. Maximum hypothetical events that were treated in SAR's traditionally have included: (1) a power burst following reactivity insertion; and (2) a loss-of-coolant (LOCA) event following normal operation. Loss of coolant flow events ordinarily are found to be less severe than LOCA events.

The specification of the reactivity insertion leading to the hypothetical power burst is affected by the available excess reactivity and by the control rod worths. The latter are important when control rods are assumed to be withdrawn without restraint; alternatively the reactivity insertion may be assumed to be from change in an unsecured experiment. The development of the power burst after initiation is enhanced for LEU fuel by the shorter neutron lifetime, by a reduced effective delayed neutron fraction, and by the longer thermal relaxation time for the fuel. If there is an over power scram trip then the reduced control rod worths may be significant. The power burst is diminished by the prompt negative U-238 Doppler coefficient of reactivity and by the larger void coefficient. These effects will cancel to some extent.

The net effect of conversion from HEU fuel to LEU fuel on initiation and development of hypothetical power bursts and LOCA events can only be determined by use of qualified computer programs. Qualification here includes the validation of the computer program against suitable experimental data, the use of the program in an SAR submittal to the NRC, and the NRC acceptance of the results. Calculations by the RERTR group for a representative MTR-type reactor benchmark indicate that for this reactor the development of hypothetical power bursts was not greatly changed by LEU conversion, although for some bursts the peak fuel temperature was slightly higher for LEU fuel[13]. These results suggest, but do not demonstrate for specific university reactors, that cancellation of the LEU conversion-associated changes in safety parameters will result in little change in predicted power burst development.

Finally, the use of LEU fuel is not expected to affect LOCA considerations substantially unless the reactor thermal-hydraulic characteristics are changed.

The preparation and defense of adequate Safety Analysis Reports can be costly both in time and effort. These costs might be reduced by several means. Generic licensing of similar reactor conversions could be very useful; here the major costs would be borne by the lead reactor (possibly under a government contract). The development of qualified computer programs for safety analysis can be very costly and should be coordinated. Even the identification of a suitably qualified existing computer program for a specific safety analysis can be costly, and guidance could be useful here. Finally, a reference document addressing NRC information needs for licensing review would be useful. This document could summarize technical information requirements and QA/QC requirements as well.

4.5 Recommendations

It is recommended that a reference document addressing NRC information needs for licensing review for LEU conversion, and summarizing technical information requirements and QA/QC criteria be provided.

It is recommended that generic licensing be applied where feasible for similar reactor conversions.

It is recommended that important safety analysis codes be qualified for SAR application and made available to those carrying out SAR analyses.

5. Schedule

Conversion of HEU fueled university research reactors to LEU fuel requires an increase in the fuel meat uranium density, an increase in fuel meat thickness, overall changes in fuel plate and element geometry, or a combination of all three. Changes in overall plate and element geometry are undesirable because they would require a major revision to the reactor's operating license, possible public hearings and intervention, core operating thermal-hydraulics analyses, and possible facility engineering modifications.

5.1 Fuel Development Schedules

In order to convert from HEU to LEU fuel and maintain the same fuel plate geometry, a reactor must have an increased uranium density, g/cc, in the fuel meat. An alternative is changed fuel plate geometry (for example increased meat thickness). This could result in an overall plate thickness increase, significant changes in core fluid flow, and alteration to heat transfer characteristics. Alternatives that produce core thermal-hydraulic modifications are undesirable because they increase the scope of the facility's license change from a minor amendment to a major revision and because they create potential expenses associated with engineering modifications to the facility.

Uranium density limits on current fuel meat technology that have been proven and operationally tested in research reactor fuels are given in Table 2.2. Test programs sponsored by the Department of Energy through Argonne National Laboratory are designed to demonstrate by the dates indicated in Table 2.2 that uranium densities can be increased to the values listed for the various types of fuels. It is possible, of course, that these schedules may not be met.

5.2 LEU Conversion Schedules

The tasks associated with conversion of a research reactor from HEU to LEU fuel are: initial program planning; safety analysis and license amendment; core physics calculations; operating thermal-hydraulics analysis; plant engineering modifications; LEU fuel specifications, procurement of fuel, and calculational confirmation of design; training of staff personnel; HEU core physics measurements and fuel disposal; and experimenal verification of reactor behavior with LEU fuel. These tasks are broken down in Table 5.1 into the more detailed requirements for each task based on the LEU conversion experience of the University of Michigan's Ford Nuclear Reactor (FNR). Four types of conversion are shown: lead and follow-on conversions involving major license revisions and lead and follow-on conversions requiring minor license amendment. The calendar times shown for follow-on conversion within a reactor type or class are shorter than for the lead reactor because follow-on reactors would benefit from the experience and analyses of the lead facility. If no fuel geometry changes are required for LEU conversion, then no core flow changes or plant engineering modifications are required; a minor license amendment, rather than a major license revision, will suffice (see Section 4). In that case the one year public hearing time block can be eliminated and a one year shortening of the conversion schedule results. Further, core operating thermal-hydraulics analysis and plant engineering modifications would not be required in this case. Elimination of these major time blocks might save overall schedule time, but they are mostly conducted in parallel with other events that would not be shortened. All times shown are estimates and may vary substantially from one facility to another.

Figure 5.1 shows a typical time-task sequence for the full core conversion of a lead reactor within a class that involved a major license revision. The times are extracted from Table 5.1. The actual time-task sequence for the Ford Nuclear Reactor is shown in Figure 5.2; associated milestones and dates are shown in Table 5.2. Conversion by gradual integration of LEU fuel into an HEU core during routine refueling would extend the conversion calendar time by the in-core residence time. Those tasks that would be eliminated where no fuel geometry changes occur are shown as dotted lines in Figure 5.1. The schedule assumes that a facility has adequate man power to perform simultaneous tasks where required. Allowance of one year for fuel procurement assumes that production schedules of the U.S. fuel manufacturers, Babcock and Wilcox and General Atomic, can produce needed fuel and that extensive special tooling and equipment are not required in the manufacturing process. Table 5.3 lists the full core elements, plates, and rods for university reactors with lifetime cores as well as for those that operate on routine refueling cycles. For fuel core conversion of university reactors to LEU fuel, totals of 421 plate elements and 389 TRIGA rods would be required. The manufacturers would have to integrate these requirements with the needs of private commercial and Department of Energy research, training, and test reactors.

The fuel manufacturers indicate that they do have the capacity to meet the fuel needs of the university reactors, but a detailed schedule would have to be worked out. Fuel manufacturers would not be willing, for example, to gear up for a massive, one-time production of fuel for converting all reactors with lifetime cores. Production for these reactors would have to be spread over a period of years. Preparation of special tooling required for a particular reactor whose fuel is not already in production would require 9-12 months. This would apply to about half of the 25 reactors in this study.

5.3 LEU Conversion of University Reactors

LEU fuel conversion of the 25 NRC licensed, university-owned reactors considered in this study is based upon the reactor fuel cycle, the type of license modification, and fuel meat technology. Reactors that operate on routine refueling cycles could periodically replace depleted HEU elements with fresh LEU elements. Ultimate full core conversion would depend on the average element residence time in the core. Reactors with lifetime cores would convert by full core replacement as a one-time event. For some reactors, LEU conversion depends upon high density uranium fuel meat technology development as was outlined in Sections 2 and 5.1. The majority should be able to convert using a direct substitution of current fuel meat technology though some fuel plate or rod internal modifications will be necessary for 16 of the reactors.

Eighteen reactors currently operate with lifetime cores, that is, refueling is not anticipated during the useful life of the facility. It is anticipated that no changes in overall plate or element dimensions would be necessary to convert three of these reactors by substitution of LEU fuel

Figure 5.1 Typical Research Reactor LEU Fuel Conversion Task-Time Schedule
(Full Core Conversion of a Lead Reactor Involving a Major License Revision)

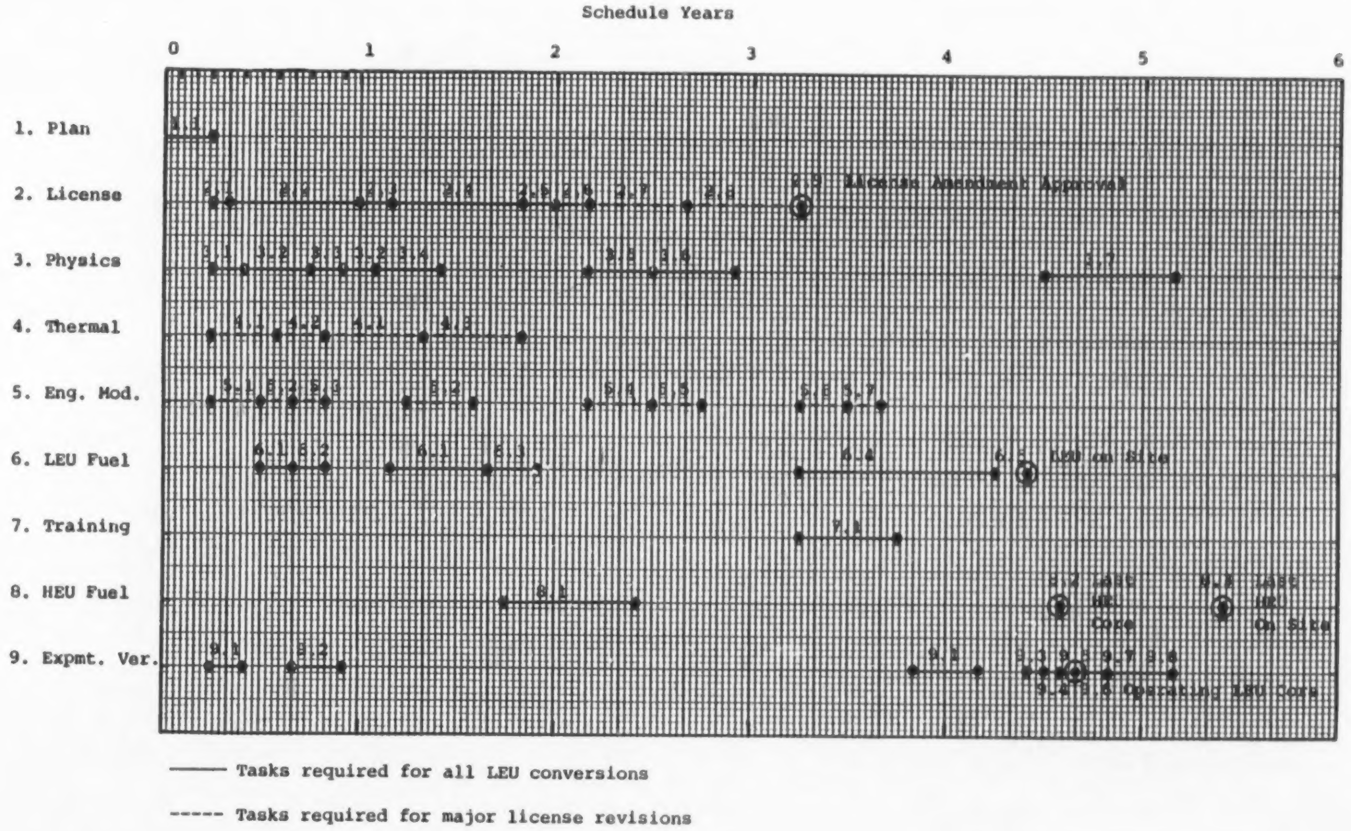


Table 5.1 Research Reactor LEU Conversion Tasks and Schedule Estimates as Exemplified by the University of Michigan Experience

	Task	Major License Rev'n		Minor License Amend	
		Lead Reactor	Follow On Reactors	Lead Reactor	Follow On Reactors
		(mo)	(mo)	(mo)	(mo)
1.	Initial Program Planning	(3)	(3)	(3)	(3)
	1.1 Planning, preparation, and scheduling	3	3	3	3
2.	Safety Analysis and License Amendment	(36)	(26)	(22)	(12)
	2.1 License amendment preparation	1	1	1	1
	2.2 Safety analysis preparation	8	4	6	2
	2.2.1 Fuel and materials historical data				
	2.2.2 Core physics				
	2.2.3 Core thermal hydraulics				
	2.2.4 Plant engineering modifications				
	2.2.5 Comparison of HEU and proposed LEU cores				
	2.2.5.1 Reduction in safety margins				
	2.2.5.2 Surveillance of safety margin limits				
	2.2.6 Design basis event and accident analysis				
	2.3 Submittal to NRC	2	2	2	2
	2.4 Initial NRC review	8	4	8	4
	2.5 Responses to NRC review questions	2	1	2	1
	2.6 Final NRC review	2	1	2	1
	2.7* Public hearing process	6	6	-	-
	2.8* Intervenor questions and responses	6	6	-	-
	2.9 License amendment approval	1	1	1	1

*Required for a major license revision, but not for a minor license amendment.

Table 5.1 Research Reactor LEU Conversion Tasks and Schedule Estimates (continued)

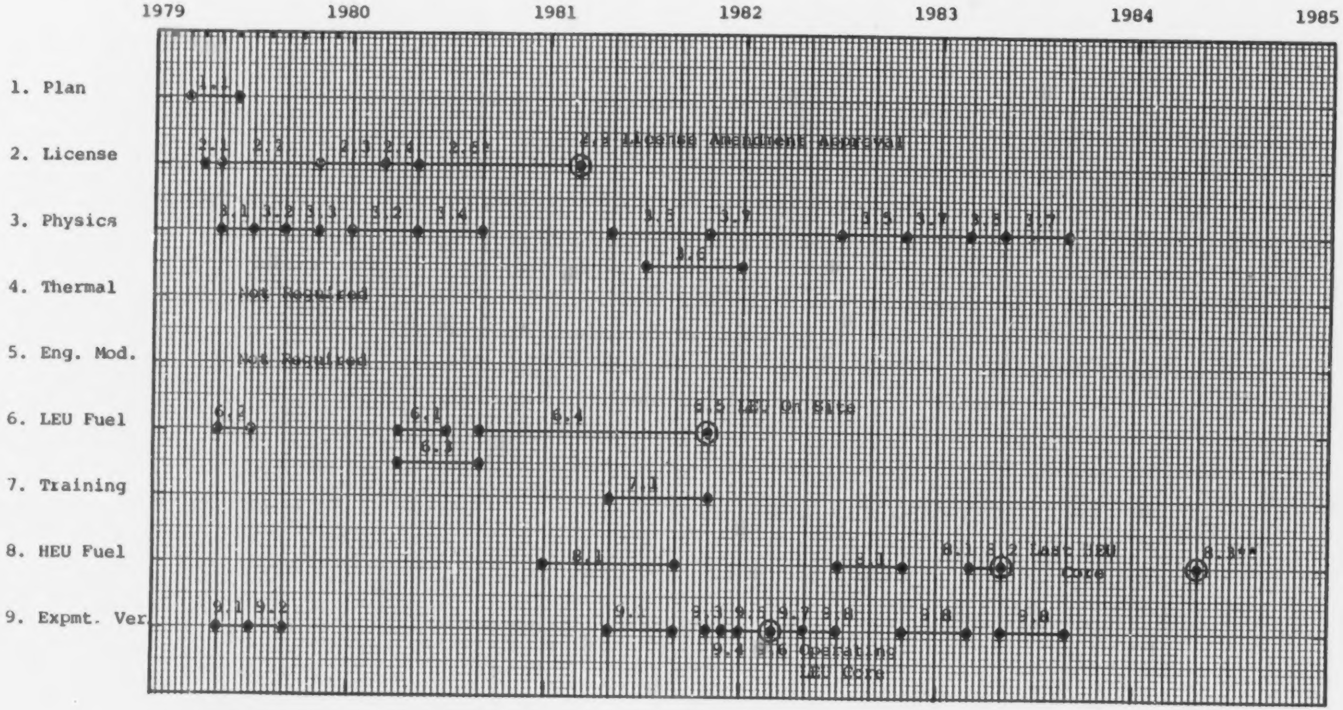
	Task	Major License Rev'n		Minor License Amend	
		Lead Reactor	Follow-On Reactors	Lead Reactor	Follow On Reactors
3.	Core Physics Calculations	(mo) (31)	(mo) (15)	(mo) (22)	(mo) (15)
	3.1 Lattice and cross section calculations	2	2	2	2
	3.2 Generic core model development and calculations	6	2	4	2
	3.3 Safety analysis support data	2	1	2	1
	3.4 External core calculations	4	2	4	2
	3.5 Verification of core models against HEU core	4	4	4	4
	3.6 Modification of lattice and core models	5	2	2	2
	3.7 Verification of core models against LEU core	8	2	4	2
4.**	Thermal Hydraulics	(19)	(6)	(0)	(0)
	4.1 Thermal hydraulics analysis	10	4	-	-
	4.2 Safety analysis support data	3	2	-	-
	4.3 Thermal hydraulics modelling and testing	6	-	-	-
5.**	Plant Engineering Modifications	(23)	(18)	(0)	(0)
	5.1 Planning	3	2	-	-
	5.2 Design	6	3	-	-
	5.3 Safety analysis support data	2	1	-	-
	5.4 Procurement	4	4	-	-
	5.5 Fabrication	3	3	-	-
	5.6 Installation	3	3	-	-
	5.7 Testing	2	2	-	-

**Required for fuel and system modifications that alter core flow, heat transfer, and fuel temperatures.

Table 5.1 Research Reactor LEU Conversion Tasks and Schedule Estimates (continued)

		Major License Rev'n		Minor License Amend	
	Tasks	Lead Reactor (mo)	Follow-On Reactors (mo)	Lead Reactor (mo)	Follow On Reactors (mo)
6.	LEU Fuel	(27)	(17)	(27)	(17)
	6.1 Fuel specifications and drawings	8	4	8	4
	6.2 Safety analysis support data	2	1	2	1
	6.3 Calculational confirmation of fuel design	3	2	3	2
	6.4 Fuel bids, procurement, and fabrication	12	8	12	8
	6.5 Fuel delivery	2	2	2	2
7.	Training	(6)	(6)	(6)	(6)
	7.1 Staff training; fuel and facility modifications	6	6	6	6
8.	HEU Fuel	(8)	(4)	(4)	(2)
	8.1 Core physics measurements on HEU core	8	4	4	2
	8.2 Last HEU use in core	-	-	-	-
	8.3 Last HEU shipment	-	-	-	-
9.	Experimental Verification of LEU Fuel	(18)	(10)	(13)	(10)
	9.1 Planning	6	2	4	2
	9.2 Safety analysis support data	3	1	2	1
	9.3 Single element insertion	1	1	1	1
	9.4 Multiple element insertion	1	1	1	1
	9.5 Critical loading experiment	1	1	1	1
	9.6 Initial full LEU core	-	-	-	-
	9.7 LEU core physics measurements (In core and ex core thermal and fast fluxes, reactivity coefficients)	2	2	2	2
	9.8 Verification of LEU core analysis	4	2	2	2
TOTAL CALENDAR TIME (Integrated Schedule)		65	51	51	37

Figure 5.2 Ford Nuclear Reactor LEU Fuel Conversion Task-Time Schedule



* Included request to increase on site contained U235 from 16.1 to 25 Kg.

** Some fresh HEU still on site

Table 5.2 Ford Nuclear Reactor LEU Conversion Schedule Milestones and Dates

Date	Milestone
March 1979	Initial program planning.
April 1979	Commenced license amendment and safety analysis preparation.
May 1979	Commenced core physics analysis, LEU fuel specifications, and planning for experimental verification of LEU fuel.
October 1979	Initial submittal of license amendment and safety analysis for NRC review.
February 1980	Completion of initial NRC review.
April 1980	Final submittal of license amendment and SAR. Oral presentation to NRC. Fuel procurement bid process commencement.
July 1980	License amendment request to increase on site contained U235 from 16.1 to 25 kg. Responses to additional NRC review questions.
February 1981	License amendments approved. Fuel order placed. Detailed core physics calculations continue.
November 1981	LEU fuel arrives on site.
December 1981	Reactor critical experiment with LEU fuel.
April 1982	Basic experimental verification of LEU fuel completed.
May 1983	Last HEU fuel use in core.
Spring 1984	Initial disposal shipment of spent HEU fuel.
Spring 1985	Finals shipment of spent HEU fuel.

Table 5.3 Research Reactor Full Core Capacity and Annual Fuel Use

	Lifetime Cores	Routine Refueling Cycle Costs Full Core	Annual Use	Manufacturer's Annual Capacity
Plate Type Fuel				
Number of Elements	269	152	102	150
Number of Plates	2,806	2,712	2,256	2,700
TRIGA Rod Fuel				
Number of Rods	290	90	20	600

utilizing current fuel meat technology. The University of California-Santa Barbara utilizes a uranyl sulfate fuel solution. No difficulty is anticipated in conversion to LEU because low enriched uranyl sulfate fuel is currently used in the identical Brigham Young University L-77 reactor. The remaining 14 reactors can be converted to LEU without dimensional changes utilizing anticipated advanced fuel technology.

Seven reactors operate on routine fuel replacement cycles. One reactor, at the University of Michigan, has converted to LEU fuel. Of the remaining six, two can be immediately converted utilizing current fuel meat technology with minor license amendments. Two additional reactors (Texas A&M and University of Virgnia-UVAR) can be converted with minor license amendments after advanced fuels become available. Full LEU conversion of the MIT and University of Missouri-Columbia reactors is not possible without fuel modification even after the scheduled 1989 verification of 7.0 g/cc uranium silicide fuels.

The results of the LEU Conversion Survey (Appendix A) of the 25 university reactors yielded the following general conversion schedule estimates and comments:

Safety Analysis and License Amendment

Preparation: 3 - 18 months; 12 month average

NRC Review: 12 months

Comments: The University of Michigan required 6 months to prepare the LEU SAR and license amendment request. A preliminary NRC review required 4 months. The final review took 10 months. None of the facilities anticipated public hearings. All anticipated minor license amendments. Public Hearings for the UCLA license renewal started in September 1980 and are yet to be completed.

LEU Fuel

Specifications: 3 - 6 months; 4 month average

Procurement: 12 - 18 months; 12 month average

Comments: The University of Michigan required 3 months to prepare specifications and 13 months to procure fuel.

Engineering Modifications

Comments: None anticipated. With anticipated advanced fuel technology, changes to overall fuel plate and element dimensions are not expected. Exceptions are MIT and University of Missouri-Columbia, if LEU conversion should be required.

LEU Experimental Verification

Test Requirements: 2 -6 months, 3 month average

Comments: One reactor response estimated 3 -4 years to recharacterize the LEU core. The University of Michigan required 5 months for essential experimental verification. The core was unavailable for approximately 2 months. Supplementary measurements were performed over a 2-year period and are still in progress.

HEU Fuel

HEU Inventory: Eighteen reactors operate with lifetime cores. The remainder would have HEU in the core for up to 9 years while following a routine fuel replacement cycle based on existing fresh fuel inventories and in core residence times ranging two to five years.

Shipment: Cooling times ranged generally 3 - 12 months. For reactors such as UCLA without shielded transfer capabilities, cooling times suggested were 24 - 60 months.

The most reasonable approach to LEU conversion scheduling would be to establish an orderly process which allows sufficient time for each reactor to complete the conversion sequence and provides a fuel fabrication schedule that is within the production capabilities of the fuel manufacturers while making allowance for fuel need dates and the availability of high density uranium fuels.

For lifetime core reactors approximately 60 months would be required for full core LEU conversion of a reactor undergoing a major license revision from initial planning to final HEU fuel shipment from the site. For a minor license amendment, the conversion can be shortened to approximately 48 months by eliminating the 12 months allowed for public hearings. Seventeen of the 25 reactors being considered are estimated to be in this 48 month category.

Reactors that operate on routine refueling cycles rather than with lifetime cores would prefer to convert by gradual integration of LEU fuel into the existing HEU core. The schedule time depends upon the the core residence time of a single element. Residence times range from two to five years. For the reactors undergoing minor license amendments, full conversion would require 72 to 108 months. For a major license revision, 84 to 120 months would be required. Five reactors are in the 72 to 108 month class; two are in the 84 - 120 month class.

Conversion at the University of Michigan, which involved a minor license amendment, started in 1979 and completion of all conversion related activities is expected to require 72 months. The conversion was a full core replacement, but with more extensive core calculations, measurements, and tests than would be required for a routine conversion.

Problem areas that provide significant uncertanties within the university community for LEU conversion time schedules are the magnitude of the license revision, the scope and length of public hearings, major facility engineering modifications, full core conversion versus conversion over a period of time by following the normal refueling cycle, the capacity of fuel manufacturers to provide the fuel needed for conversion in a timely manner, the availability of a spent fuel shipping cask, the cost of spent fuel shipment, and the basic conversion costs of new fuel and analysis.

5.4 Recommendations

It is recommended that the NRC carefully consider in the course of rule making the capabilities of the fuel manufacturers to handle the LEU conversion fuel fabrication schedule.

It is recommended that the NRC encourage the timely licensing of spent fuel shipping casks as required for the LEU conversion schedule.

It is recommended that the NRC encourage the carrying out of the advanced fuel development program as scheduled.

It is recommended that the NRC encourage the provision of federal funds for all phases of LEU conversion: analyses, facility modifications, new fuel, startup tests with new fuel, and spent fuel shipment.

It is recommended that the NRC encourage the carrying out of the advanced fuel development program as scheduled.

6. Recommendations

The LEU Study Group recommends that the cost of returning unused or partially used HEU fuel be carefully considered in the course of rule working. An economic penalty on the order of $10,000 -$20,000 per fuel element would result if a new regulation would prohibit the use of such unused fuel either in storage at the reactor site or at another location.

It is recommended that consideration be given to the significant savings in direct and indirect costs if conversion to LEU were not to be required until a suitable type of advanced fuel has been demonstrated and becomes available. A desirable advanced fuel will enable a reactor to convert to LEU either by direct substitution or by increasing the fuel meat thickness without increasing the total plate thickness. In this case no thermal-hydraulics changes would be required.

Where conversion to LEU is not technically feasible in the near future, the LEU Study Group recommends that consideration be given to reduction of proliferation risk through the use of medium enriched uranium (MEU) fuel and, through decreased HEU traffic by utilizing advanced fuels technology in combination with HEU.

It is the primary recommendation of this study that, if conversion to LEU fuel is mandated by the NRC, then adequate funding for this conversion must be provided by the federal government. Otherwise, many university-based reactors may have to be shutdown. It is recommended that the NRC encourage the provision of federal funds for all aspects of LEU conversion: analyses, facility modifications, new fuel, startup tests with new fuel, and spent fuel shipment.

It is recommended that the NRC establish a priority system for LEU conversion. The factors that would affect this priority list include: (1) LEU fuel availability and cost; (2) fuel consumption; (3) fuel cycle costs for fabrication and shipping. It is recommended that the highest priority for LEU conversion should be for plate-type reactors having 0.2Mw<Power<2 Mw, since the fuel technology is reasonably assured, and this group comprises a significant fraction of all university reactors. The second priority should comprise the remaining low power reactors. The third priority should be for reactors with Power > 2Mw and with high power density. This group comprises only 2 reactors for which LEU fuel is not currently available and the costs of conversion will be much higher than for the lower power group.

A recommendation that would offer substantial cost savings is that lead reactors be identified for each group of similar reactors. These reactor staffs would develop SAR's and related documentation which could be used by the other reactor staffs as guides or for generic licensing.

It is recommended that a reference document addressing NRC information needs for licensing review for LEU conversion, and summarizing technical information requirements and QA/QC criteria, be provided.

It is recommended that generic licensing be applied where feasible for similar reactor conversions.

It is recommended that important safety analysis codes be qualified for SAR application and made available to those carrying out SAR analyses.

It is recommended that the NRC carefully consider in the course of rule making the capabilities of the fuel manufacturers to handle the LEU conversion fuel fabrication schedule.

It is recommended that the NRC encourage the timely licensing of spent fuel shipping casks as required for the LEU conversion schedule.

It is recommended that the NRC encourage the carrying out of the advanced fuel development program as scheduled.

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The LEU Study Group is deeply grateful for the cooperation of many people from the university reactor community, from the DOE, and from the NRC. We are indebted to Ms. Nancy Gallagher and Ms. Kathy Lineaweaver for their efficient and cheerful assistance in typing and assembling the report.

APPENDIX A

LEU Conversion Survey

INQUIRY LETTER
LEU Conversion Survey

Department of Nuclear Engineering

Rensselaer Polytechnic Institute Troy, New York 12181

August 29, 1983

L. Clark, Jr., Reactor Operation
Director
MIT Research Reactor (MITR-II)
Nuclear Reactor Laboratory
138 Albany Street
Cambridge, Massachusetts 02139

Dear Colleague,

The USNRC is considering requiring that NRC-licensed research, test, and training reactors use fuel with no greater than 20 w/O enrichment (LEU). An NRC-sponsored LEU Study Group, of which I am the Chairman, is assessing the licensing, feasibility, scheduling, and functional implications of such a policy for university reactors. The other members of the study group are Lincoln Clark of MIT, currently Chairman of the TRTR organization, Professor Thomas Parkinson, Chairman of the UPI Nuclear Engineering Department and member of NEDHO, and R. Robert Burn, Manager of the Ford Nuclear Reactor, the demonstration unit for LEU conversion. Dr. Charles Kelber of the USNRC Office of Accident Evaluation, is monitoring the project.

The purpose of this letter is to inform you concerning the matter and to request certain written material in support of university interests. This letter is being sent only to those university reactors which would be affected by LEU conversion.

An NRC Office of Policy Evaluation paper (J. Zerbe to Commissioner Ahearne, March 1, 1983) has defined several options. These options range from the permissive to the stringent, specifically, "Immediate replacement of the cores of those existing reactors capable of using LEU." A target date for release of a rule for comment is January 1, 1984.

University reactors can benefit from use of LEU in reduced concern for potential terrorist activity, and, in some cases, from reduced physical security requirements. On the other hand, there are potential costs, including LEU conversion-related costs for new fuel, for fuel shipment and handling, for engineering modifications, if any, for SAR preparation, verification, and defense, for revised fuel cycle, for lost revenue during conversion, and for lost revenue due to degradation of performance. For several reactors the use of LEU fuel may result in degraded performance of the reactor unless advanced fuels become available, e.g., under the RERTR Program. The continued effectiveness and even the existence of some university reactors may be jeopardized by such potential costs and degraded performance.

The LEU Study Group, in its assessment function, can reflect university interests in the policy and rule making process. Some costs of LEU conversion may be borne by U. S. government agencies. We are informed that now is the time for most effectively influencing the supply of U. S. funding for this purpose.

For these reasons we are requesting written responses dealing with the questions listed below. The responses will be appended to our report to the Commissioner in early November. The requested information is not exhaustive and may be accompanied by related material as you see fit. However, we do suggest that you express your situation as informatively and strongly as possible. A concise summary of your position also will be useful.

All the following items concern the effects of LEU conversion for your reactor only.

1. Functional Impacts

a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Please consider costs of decommissioning if applicable.

e. What would be the net cost/benefit of conversion of your reactor to LEU?

2. Licensing

a. Safety-related technical problems, if any.

b. Man-month requirements for SAR preparation and defense.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium buildup.

d. Problems related to additional hearings and other public processes, if any.

e. Would a NUREG licensing guide be useful to you?

3. Feasibility

The NRC "Statement of Policy", August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U. S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs". Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

b. Based on use of advanced fuels once these are demonstrated and available?

4. Scheduling

a. How many grams of unirradiated/irradiated HEU fuel have you on hand?

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?

e. Calendar time to prepare SAR and license modifications.

f. Calendar time to prepare LEU fuel specifications and drawings, and to obtain fuel based on your experience.

g. Calendar time to plan and effect engineering changes, if any.

h. Calendar time to carry out additional LEU-related start tests.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.

j. How long afterward could you ship your last HEU fuel?

We greatly appreciate your attention to this matter. Although some of the questions above are difficult, they are important to continuing the important work of university reactors. You may not wish to respond to all the questions at this time, and you may wish to provide other information. A brief response is better than none. We hope to receive your response by September 9, 1983, but responses will be considered for some time thereafter. We expect to contact you by telephone as well.

Sincerely,

D. R. Harris

Dr. Donald R. Harris, Chairman
LEU Study Group
DRH:mb
cc: R. R. Burn
L. Clark, Jr.
C. Kelber
T. F. Parkinson

RECEIVED
MIT-NUCLEAR REACTOR LABORATORY
SEP - 2
138 ALBANY ST
FILE:

UNIVERSITY OF MISSOURI

October 27, 1983

Dr. Donald Harris, Chairman
LEU Study Group
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Dr. Harris:

This letter is in answer to your request for information concerning the effect of the LEU program on the University of Missouri Research Reactor (MURR). To save space, the answers will be given in the same outline form as the questions are asked in your enclosed letter dated August 29, 1983.

1. a) There will be no significant benefit to MURR in using LEU. Since there is not a LEU fuel available for use in MURR, it is hard to define what the costs will be with conversion. One defined cost is the $50,000,000 being spent by the RERTR program. With respect to federal budgets, this is small but much greater than the combined annual operating budget of all U. S. university reactors. What percentage of this cost that is attributable to developing Silicide LEU for MURR and MIT is not known by us. The other costs could range from $100,000 to well over One Million Dollars depending on various contingencies such as favorable review, time allowed for converting, if the need for public hearings develop, etc.

   b) Will not be able to answer this question until a LEU fuel usable in MURR is developed and the problems associated with it are further analyzed.

   c) Will not be able to answer this question until a LEU fuel usable in MURR is developed and the problems associated with it are further analyzed.

   d) MURR would convert to LEU if it could be demonstrated the reactor's performance is equivalent with LEU as that obtainable with HEU with comparable costs in the overall fuel cycle cost.

   e) It is not possible to clearly define the cost associated with conversion at this time. However the range of potential costs is very large compared to the negligible benefit to MURR.

COLUMBIA KANSAS CITY ROLLA ST. LOUIS

2. a) Currently LEU fuel elements loaded to the U-235 grams/cc required to operate our reactor would fail at low burnup levels, i.e. fuel element failure.

   b) Assuming technical assistance from RERTR and a reasonable NRC response, it would take approximately 12 man-months.

   c) Will not be able to answer this question until a LEU fuel that can be used in MURR is developed and the problems associated with it are further analyzed.

   d) Best answer is to reference the hearings and associated problems concerning the UCLA and AFRI reactors.

   e) Yes, if it is limited to what is required to meet regulations and not expanded as is the usual case to include what the NRC would like to see above and beyond the regulation requirements.

3. a) Based on fuel with existing technology, MURR cannot operate on LEU fuel. To obtain high performance (good ratio of peak thermal flux to reactor power), our reactor was designed around a small under moderated heavily loaded HEU core. To use LEU would require increasing the fuel meat volume to the point where there will be insufficient water volume left for the required coolant and moderator volume.

   b) This would be using silicide fuels of very high uranium loading. There is insufficient information available to answer this question. Additional analysis will have to be done after detailed review of the results obtained during the silicide fuel demonstration.

4. a,b, and c)

   The MURR core uses 8 fuel elements loaded to 775 grams/elements. Our fuel cycle burns out 24 elements per year to approximately 145 MWD by refueling weekly with a core that has approximately 510 MWD total power history. Therefore a fuel element will be loaded in the reactor between 15 and 20 different times. *Our new fuel elements shipments are spread out over the year and we ship spent fuel so that our on hand inventory cycles between the following ranges and averages close to the midpoint of the range.

Unirradiated	0 - 4.9 Kg	U-235
Irradiated + Unirradiated	30 - 44.9 Kg	U-235

   d. Use of LEU is too undefined to speculate at the effect on fuel cycle. Further analysis will be required after a usable LEU is demonstrated.

   e. Minimum of 12 months would be required assuming most favorable review by NRC.

*Fuel shipping schedules are discussed in general terms because of concern for safeguards.

#4 (Cont'd)

f) One year would be required assuming no major design change from current fuel elements.

g) The type of engineering changes research reactors are using to facilitate use of LEU were incorporated in MURR's original design to make the core compact for optimal performance. See answer 3a.

h) Start-up tests for a significant change in fuel would require 20 operational days distributed over a 24 month period.

i) The current assembled HEU fuel elements will last till March 1985 without any additional fuel elements. Then additional fuel elements would have to be inserted in the fuel cycle and it would take till March 1987 for the last of the currently assembled fuel elements to be burned out.

j) MURR fuel needs to decay for at least 150 days and an average of 220 days before shipping.

If a clarification needs to be made in any of the contained information, please call me at (314)-882-4211.

Sincerely,

J. C. McKibben
Reactor Manager

JCMK:vs

Enclosures

cc w/encl.: Lincoln Clark, Jr.
Robert Brugger
Don Alger

Cost for shipment of spent fuel for 3350 MWd per year.

	Enrichment			
Loading	93.15%	83.15%	65%	45%
1.6	$32,200	$56,000	α	α
1.9	18,200	26,600	$117,600	α
2.1	14,000	19,600	49,000	-α
2.4	11,200	15,400	30,800	α
2.6	9,800	12,600	23,800	α
2.9	8,400	9,800	18,200	$123,200
3.2	7,000	8,400	14,000	53,200

NOTE: The symbol "α" implies that the reactor will not be critical with this core loading.

NOTE: Cost for shipment of spent fuel is ~ $1400.00 an element in 1983 dollars.

U-235 used each year for 335C MWd.

	Enrichment			
Total Uranium Loading	93.15%	83.15%	65%	45%
1.6	17.8 Kg	27.7 Kg	α	α
1.9	11.9 Kg	15.6 Kg	53.8 Kg	α
2.1	10.3 Kg	12.9 Kg	25.2 Kg	α
2.4	9.2 Kg	11.3 Kg	17.6 Kg	α
2.6	8.7 Kg	10.1 Kg	14.8 Kg	α
2.9	8.4 Kg	8.8 Kg	12.7 Kg	59.7 Kg
3.2	7.8 Kg	8.4 Kg	10.9 Kg	28.6 Kg

NOTE: The symbol "α" implies that the reactor will not be critical with this core loading.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Univ. Missouri (Columbia)*

1. Functional Impacts

a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

Not technically or economically feasible with current fuel technology or with LEU fuel under development by RERTR.

b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

Further study would be required because fuels that would be required have no operational history.

c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

Same as 1-b.

d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Plese consider costs of decommissioning if applicable.

MURR would be supportive of LEU conversion if it could be demonstrated to provide equivalent performance of the reactor as obtainable with HEU.

e. What would be the net cost/benefit of conversion of your reactor to LEU?

Estimated to be extremely high.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Univ. Missouri (Columbia)*

2. Licensing

a. Safety-related technical problems, if any.

Fuel integrity with required high U loading.

b. Man-month requirements for SAR preparation and defense.

12 man-months if no fuel geometry changes and no additional questions and concerns raised by NRC.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

None now identifiable, but this is an open question relative to reprocessing until resolved by DOE.

d. Problems related to additional hearings and other processes, if any.

Please refer to UCLA experience; has potential for very high cost.

e. Would a NUREG licensing guide be useful to you?

Yes, if limited to requirements of regulations and omits information merely desired.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Univ. Missouri (Columbia)*

3. Feasibility

The NRC "Statement of Policy," August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs." Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

Would require power reduction.

b. Based on use of advanced fuels once these are demonstrated and available?

Even if advanced fuels are demonstrated, additional studies would be required as indicated in Question #1.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Univ. Missouri (Columbia)*

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?
Unirradiated 0-4 kg
Irradiated 30-45 kg

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?
Receive an average of 24 elements per year and refuel roughly weekly.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.
See 4-b.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?
Phase in with mixed core subject to licensing approval.

e. Calendar time to prepare SAR and license modifications.
At least one year under most favorable conditions.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.
1 year.

g. Calendar time to plan and effect engineering changes, if any.
Engineering changes not feasible.

h. Calendar time to carry out additional LEU-related start tests.
One month reactor time spread out over 18 months, plus additional analytical time.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.
3 years.

j. How long afterward could you ship your last HEU fuel?
5 months.

October 27, 1983

MIT Research Reactor (MITR-II)
Effects of Conversion to LEU
(Response to LEU Study Group Survey Letter of 8/29/83)

Summary

In the late 1960's and early 1970's the MIT Research Reactor was redesigned in order to optimize the beam port thermal neutron fluxes for use in spectrometry. A concomitant benefit was an increased fast neutron flux in-core for use in radiation effects studies.

In order to accomplish the above, advantage has been taken of state-of-the-art technology in the fabrication of plate-type fuel, a technology that has been little improved since that time, although prospects for advances in the next few years are favorable. First, the maximum demonstrated uranium concentration in the UAl_x-Al fuel meat is used, i.e. 42 w/o U (1.6g U/cm^3). Second, a fuel meat having a thickness of 0.030" (0.76 mm) is used, which reduces the coolant gap to the minimum acceptable. MIT also adopted a unique finned plate surface, which nearly doubles the heat transfer coefficient and permits removal of the 5 MW design power without excessive clad-to-coolant temperature differences. Figure 1 illustrates the fuel. A heavy water inner reflector surrounded by a graphite outer reflector further optimizes neutron fluxes in the experiment facilities.

The MITR-II is a tank-type reactor, actually a double tank. An inner tank 20" (51 cm) in diameter at its bottom where the core is located holds an aluminum weldment that in turn holds the hexagonal core, 15" (38 cm) across the flats, and also the six tangential shim blades. The heavy water reflector is held in a 48" (122 cm) diameter tank that just fits inside the graphite reflector. The configuration is illustrated by the vertical and horizontal sections through the core shown in Figs. 2 and 3.

The reactor operates with 23-25 of the 27 available fuel positions occupied by fuel with the remaining two-four positions filled by irradiation facilities (a solid aluminum dummy element may fill one of the positions, depending on the fuel loading and experiment requirements). Experience with nearly eight years of MITR-II operation has resulted in about 42% average U-235 burnup. Elements reach the 1.8 x 10^{21} f/cm^3 limit imposed by the Technical Specifications at about the same time that reactivity loss requires refueling.

It should be obvious from the above description that there is no leeway, given the current status of research reactor fuel technology, for any reduction in MITR-II fuel enrichment to MEU or LEU without a substantial degradation in reactor characteristics or in fuel cycle performance. There is no way in which more uranium can be accommodated in the core without completely replacing the core housing and core tank, both very expensive modifications (based on experience with doing this when changing from MITR-I to MITR-II); and any reduction in enrichment, without a compensating increase in total uranium content will substantialy increase fuel cycle costs with MEU, and it probably will not be possible even to get critical with LEU.

Only the development and demonstration of advanced fuels, with total uranium concentrations many times those currently available, will permit a reduction of U-235 enrichment in MITR-II fuel without a substantial degradation in performance or a substantial increase in fuel cycle costs. With this background in mind, information regarding the effects on the MITR-II of conversion to MEU or LEU can be provided as requested in the LEU Study Group letter dated August 29, 1983.

1. Functional Impacts

   a) Costs:

   Fuel fabrication costs for MITR-II are now in the range of $200,000-300,000/year. With reduced enrichment (but no other changes), resulting in shorter fuel lifetime in the reactor, the cost would escalate to infinity at the point where enrichment reduction shortens the fuel lifetime in the core to a negligible value. Any enrichment reduction, without new technology to permit a higher loading, will result in not only higher fuel costs, but more fuel in fabrication, in transit and in reprocessing, plus higher radiation exposures and greater quantities of high level waste for disposal.

Furthermore, the structural constraints described above preclude even minor modifications that would permit increasing the total uranium in the core significantly, e.g. by increasing the size of the core; hence, only a total redesign and multimillion dollar rebuilding would permit uses of MEU or LEU with today's fuel technology. The research revenue loss of several hundred thousand dollars during the conversion, pre-operational and startup tests would probably be less important than the disruption and perhaps permanent loss of established research programs.

b) Functional capability:

Without advanced fuels, the duty cycle will be reduced by use of MEU or LEU, with higher fuel cycle costs as discribed above. The successful demonstration of advanced fuels (higher uranium contents than any now apparently under development) might alleviate the problem, but further study will be required to evaluate the nature and magnitude of any changes in core parameters. The assistance of the ANL RERTR program in such studies may well be required.

c) Changes in technical performance:

Given the successful demonstration of advanced fuels, the effects of changed technical performance on research, training and test programs would probably not be significant, except for the expenditure of time, effort and funds to remeasure neutron levels and spectra in the various experiment facilities.

d) MIT response to LEU conversion costs:

Any significant costs of LEU conversion that MIT might be forced to assume would very likely result in closing down of the MIT Reactor. MIT spent three million dollars of its own funds to upgrade and overhaul the reactor in the mid-1970's, and it has had to absorb operating deficits since that time. It is unlikely to absorb any significant additional costs, even though decommissioning of the reactor would probably entail expenditures in the range of one to two million dollars, depending on the mode of decommissioning elected.

e) Net cost/benefit of conversion:

The numerator of this ratio, costs, will be excessive for conversion to LEU without advanced fuel technology. With it, the costs at best may be mostly financial and in the range of two to four hundred thousand dollars for SAR preparation, startup tests, and remeasurement of core parameters, neutron levels and spectra. MIT would seek outside funding to help defray these costs.

The denominator, benefits, is difficult to quantify. Reduced concern for potential terrorist activity is a benefit. However, the concern should be small in any event, because only a terrorist with some experience and intelligence would consider theft of SNM from a reactor facility, and such a terrorist would have sufficient knowledge to appreciate that the MIT inventory of SNM is not an attractive target, i.e. the unirradiated SNM is always less than a formula quantity, 5 KG, and the remainder is orders of magnitude more radioactive than the "self-protecting" level (100 R/hr at one meter) established by NRC regulation. In addition, by MIT policy, the unirradiated SNM on hand is normally maintained at a small fraction of the permissible 5 KG, rendering the target even less attractive.

A reduction in physical security requirements is an appealing prospect, but this is somewhat nebulous so long as physical security is required to protect against radiological sabotage.

The net cost/benefit ratio for conversion to LEU, under either present or advanced fuel technologies, can only be viewed as very high.

2. Licensing

For purposes of answering questions in this Section 2, it is assumed that conversion to LEU will be accomplished only with advanced fuels, since conversion with today's fuels is not technically feasible and would not be attempted.

a) Safety-related technical problems:

Provided that advanced fuels make it possible to maintain the same fuel geometry (number of plates, plate and coolant gap thicknesses, etc.), no safety-related technical problems have yet been identified. If geometry is changed, it will be necessary to re-examine the core thermal-hydraulics, the neutron flux peaking, reactivity accidents, etc., and it is too early to tell if problems will be found.

b) Man-months for SAR changes:

Changes to those sections of the SAR dealing with the fuel description,performance, and management, core parameters (reactivity coefficients, lifetime, burnable poisons, etc.), flux levels, peaking and spectra, excess reactivity and control, etc., will require about six man-months of staff time (roughly estimated), even if core geometry remains constant. This could increase by a factor of two or three if geometry changes require more extensive studies.

c) Licensing problems for the fuel cycle.

Licensing problems for fuel fabrication and for fresh fuel shipping should be reduced where LEU instead of HEU is involved.

In the reactor, plutonium should not present problems except in the case of a fuel melt where Pu becomes distributed throughout the primary cooling system in amounts sufficient to become a health hazard during systems maintenance. (It is also generated in HEU, but in amounts 10-20 times less.)

The use of LEU does not lead to any licensing problems in the shipping of spent fuels of which we are aware. Those familiar with reprocessing are better able than we to identify and evaluate any problems in the backend of the fuel cycle arising from LEU, including Pu buildup.

d) Public hearings:

If a public hearing should be required it could add one hundred thousand dollars or more in costs for staff, consultant and legal involvement, such as the University of California at Los Angeles Research Reactor is now experiencing. Loss of research and training activities and income would be in addition.

e) Licensing guide:

A NUREG or other licensing guide would be a useful document provided that it is limited to safety-related fuel conversion matters, serves as a model and is not just an excessively long list of items to be addressed, and is available in time to be used in developing the necessary conversion studies and the subsequent preparation of a safety analysis report.

3. Feasibility (technically possible and no significant economic penalty)

a) Using today's fuels:

The feasibility of converting to LEU using fuels fabricated with existing technology was addressed in the opening Summary. The Reduced Enrichment for Research and Test Reactors Program (RERTR) has proposed a number of changes in fuel design that would make it feasible for some reactors to convert to LEU, including higher uranium loading and thicker fuel plate cores. As pointed out in the Summary, the MITR-II design has already incorporated state-of-the-art technology in both of these areas, so that these options cannot presently be used to compensate for lower enrichment. Any reduction in enrichment, therefore, would reduce reactivity and fuel lifetime and, correspondingly, increase fuel cycle costs.

b) Using advanced fuels:

If uranium enrichment is reduced from 93% to 20%, total uranium must be increased by a factor of 4.7 to provide the same U-235 content without a change in the geometry of the fuel. Additional U-235 must be added to compensate for the extra U-238 neutron absorption, and reactor physics calculations will have to be performed to estimate the amount. If 15% is used as an approximation, the present MITR-II loading of 1.6 g U/cm^3 will have to be increased to about 8.6 g U/cm^3. This is beyond the 7.0 g U/cm^3 presently judged by the RERTR program to be the maximum loading achievable (U_3 Si - Al), and so it is likely that an intermediate enrichment (MEU) will be required for MITR-II fuel if reactor performance and fuel cycle costs are not to be significantly degraded.

4. Scheduling

a) The MITR-II fuel inventory is approximately 1 KG unirradiated and 27 KG irradiated HEU.

b) The next fuel delivery and refueling will be in January or February 1984.

c) With HEU fuel, the steady state fuel requirements are 6-8 elements/year. Assuming the availability of advanced fuels with about 15% more U-235 content and the same 42% burnup, fuel requirements should decrease to about 5-7 elements/year. If the U-235 content is reduced, so that less reactivity is available from the fuel, more frequent refuelings would be required.

d) Under steady state refueling conditions, elements will operate in the reactor about 4-5 years, and 6-7 years will elapse from initial insertion to final discharge, including time spent in temporary storage between periods of use in the reactor. This intermittent utilization is part of a fuel management scheme aimed at achieving the maximum possible average burnup. When advanced LEU fuel becomes available, it will be desirable to cycle it gradually into the core, running mixed cores for a period of about seven years.

e) The calendar time required to prepare an SAR modification and a license amendment application would be about a year, and these could not be submitted until some months after the advanced fuel to be used has been thoroughly demonstrated and adequately documented to the satisfaction of the Nuclear Regulatory Commission. NRC approval of such an application could well require another year or two.

f) The calendar time required to prepare LEU fuel specifications and drawings, to qualify the fabricator, and to manufacture a batch of fuel would probably require 1-1 1/2 years, assuming there was no significant conflict with other demands on the vendor.

g) As indicated in the Summary, the conversion of MITR-II to LEU or MEU must be accomplished through the development of advanced fuels and not through modification of the reactor (i.e. engineering changes).

h) Startup tests on an entire LEU core will probably not be feasible because of limited storage facilities for irradiated fuel. Also, it would be expensive to provide an entire core of LEU at one time as opposed to phasing it in gradually as described above in (d). The latter course assumes that meaningful "startup" tests and measurements can be made for LEU elements in a mixed core and that NRC approval can be obtained for such operation. It would probably be necessary to remeasure important core characteristics a number of times as LEU elements constituted a larger and larger fraction of the core, e.g. fuel element reactivities, control blade worths, void and temperature coefficients in the core, H_2O and D_2O reflectors, neutron lifetime, moderator and absorber reactivities, and perhaps others. Measurements of the LEU effect on neutron levels and spectra would also be necessary. A very rough estimate of the cumulative time required for these activities is three to six months.

i) Sixteen unused elements are in process or already fabricated, and these will be cycled into the reactor over the next two years approximately. Adding seven years to achieve maximum burnup makes a total of nine years to burn all the HEU fuel. It should be pointed out, however, that after about two years, when all HEU fuel has been inserted in the reactor, the remaining irradiated HEU becomes a very unattractive target for terrorists, as mentioned earlier.

j) It should be possible to ship the last HEU fuel three to six months after it has been removed from the reactor, assuming that delays are not encountered in the scheduling of spent fuel shipments.

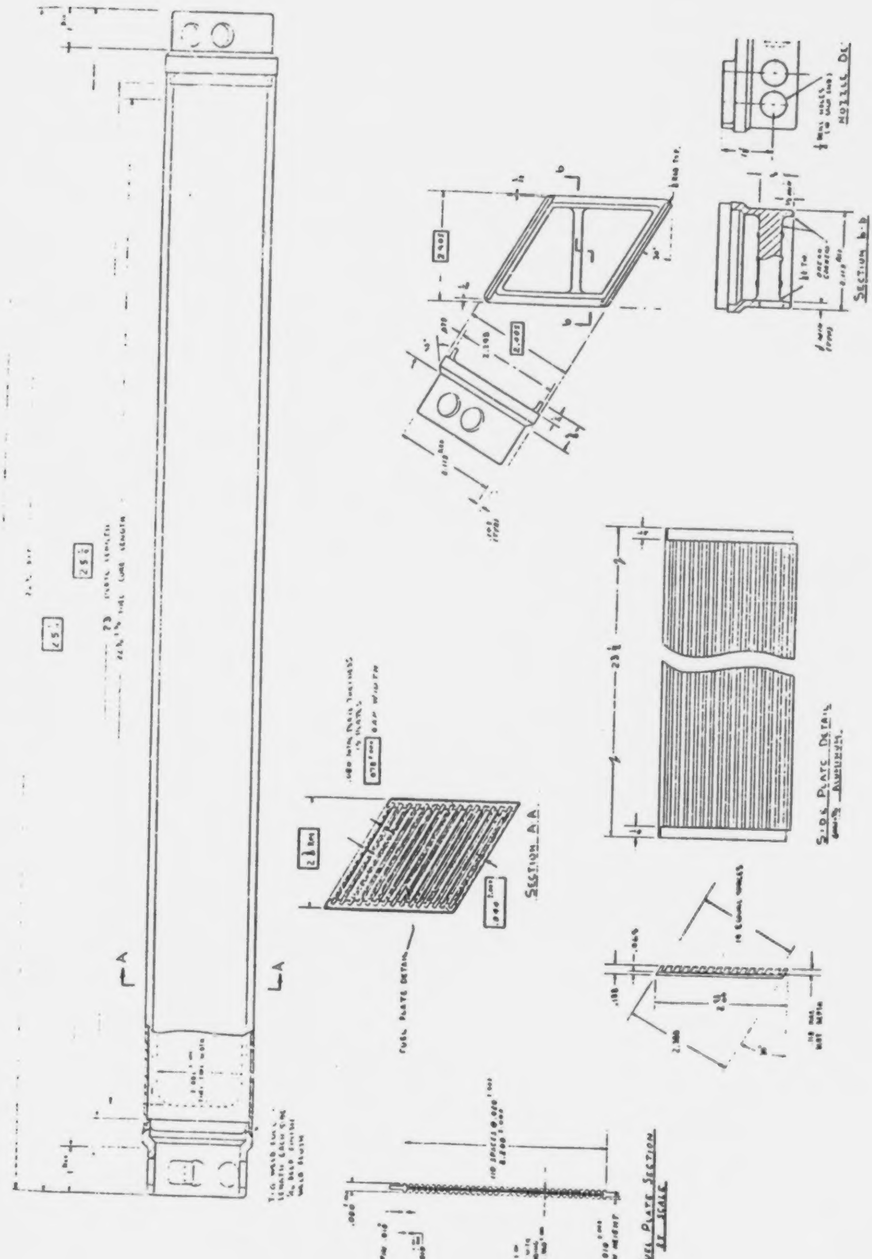
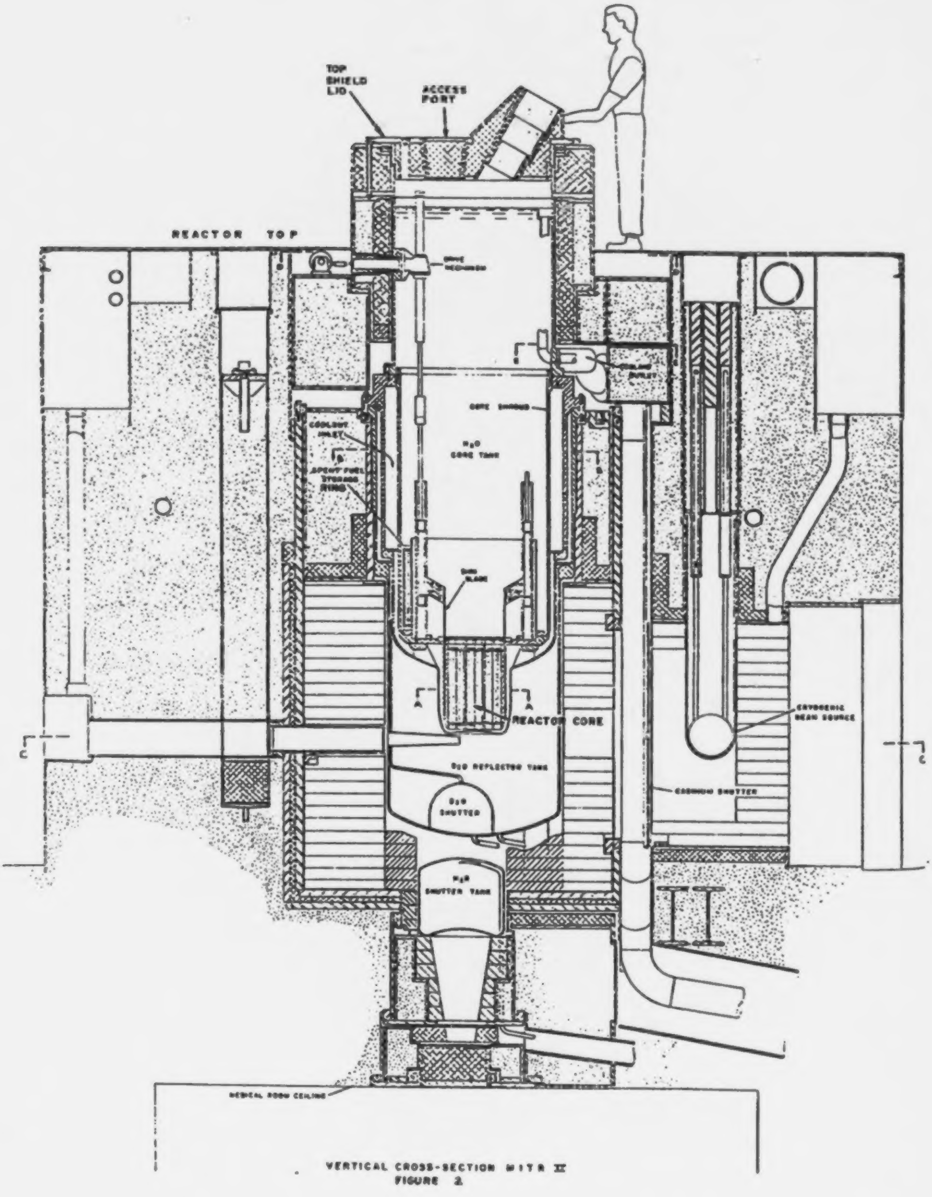

SECTION A-A
FUEL PLATE DETAIL
SIDE PLATE DETAIL
SECTION b-b
FUEL PLATE SECTION
A
A

FIGURE 1
MITR-II FUEL ELEMENT


TOP SHIELD LID
ACCESS PORT
REACTOR TOP
DRIVE MECHANISM
CORE SHROUD
COOLANT INLET
SPENT FUEL STORAGE RING
H_2O CORE TANK
B
B
A
A
REACTOR CORE
C
C
D_2O REFLECTOR TANK
D_2O SHUTTER
H_2O SHUTTER TANK
CRYOGENIC BEAM SOURCE
CADMIUM SHUTTER
MEDICAL ROOM CEILING

VERTICAL CROSS-SECTION MITR II
FIGURE 2

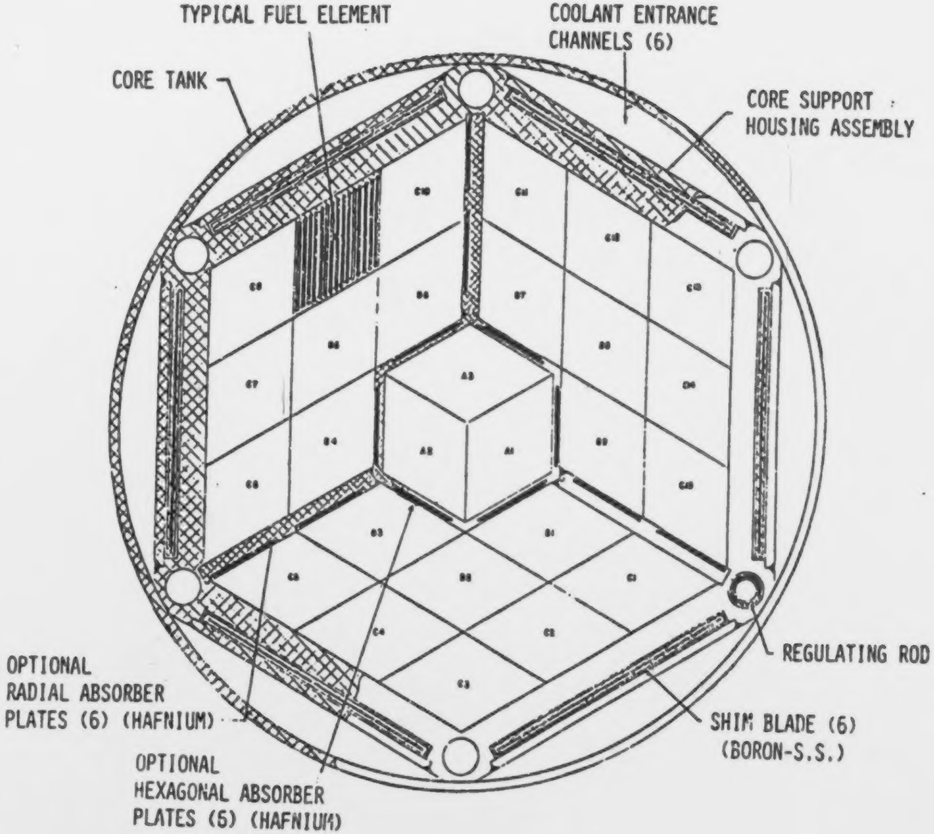

TYPICAL FUEL ELEMENT
COOLANT ENTRANCE CHANNELS (6)
CORE TANK
CORE SUPPORT HOUSING ASSEMBLY
A3
A2
A1
REGULATING ROD
OPTIONAL RADIAL ABSORBER PLATES (6) (HAFNIUM)
SHIM BLADE (6) (BORON-S.S.)
OPTIONAL HEXAGONAL ABSORBER PLATES (5) (HAFNIUM)

FIG. 3 CORE SECTION M.I.T.R.-II

Georgia Institute of Technology
SCHOOL OF NUCLEAR ENGINEERING AND HEALTH PHYSICS
ATLANTA, GEORGIA 30332

NEELY NUCLEAR RESEARCH
CENTER

October 25, 1983

Dr. Donald R. Harris
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Dr. Harris:

This is in response to your recent letter concerning the potential impact of a possible NRC requirement that reactors such as ours use low enrichment uranium (LEU) fuel. The Georgia Tech reactor would definitely be impacted by such a requirement. I am providing brief responses to the several questions in your letter.

1. Functional Impacts

   a. LEU fuel for the Georgia Tech reactor is estimated at approximately $200,000. We further estimate an additional $200,000 for fuel shipping, SAR preparation and defense, loss of revenue and low power physics testing. It is not clear at this time that any significant benefit costs would result from conversion.

   b. Based upon the experience of the University of Michigan and our own preliminary calculation, the effects would not be very large (perhaps 10%) but additional studies would be required.

   c. Those irradiation programs which require certain specific activities would be undesirably impacted. This would reduce the revenue for those short-lived isotopes produced at the facility.

   d. If any significant expense to the Institute for LEU conversion were involved it would lead to shutting down the reactor. Technical assistance for SAR revisions would be required.

   e. The cost-benefit ratio is expected to be high.

2. Licensing

    a. None anticipated

    b. We estimate that 3 to 6 man-months effort would be required for the SAR preparation and defense assuming that no fuel geometry changes would be required.

    c. None presently recognized but the fuel reprocessors should be contacted.

    d. Please refer to the UCLA experience.

    e. A model licensing application containing answers would be more helpful than a detailed guide that provides only a format. In any event, the guidance should be limited to LEU conversion.

3. Feasibility

    a. With existing technology, it might not be possible to achieve criticality. Even if the reactor could be operated there would be a very short fuel lifetime resulting in excessive fuel costs, refueling time, radiation exposure, shipping costs, etc. Various experiments would be severely impacted due to low excess reactivity.

    b. Using to-be-developed advanced fuels, no impact other than the above noted flux reduction.

4. Scheduling

    a. We currently have less than 5 kg. of unirradiated HEU fuel and approximately 4 kg. of irradiated fuel.

    b. The present inventory is sufficient so that new fuel will not be required for several years.

    c. No refueling is presently scheduled for purposes of adding reactivity.

    d. LEU fuel would be phased in as required for additional reactivity (but see 4c).

    e. We estimate 6 to 12 calendar months for SAR and license modification.

    f. We estimate 12-18 calendar months to prepare LEU fuel specification and drawings and to obtain the fuel.

g. No engineering changes are anticipated.

h. The LEU related start-up tests would require a few man-months spread out over many years as the LEU fuel is phased in.

i. With our present schedule, HEU fuel burnup will not be achieved for several years.

j. Shipment could probably be made in 6 months.

I hope the above answers will be of help to your committee. Should clarification or expansion of any item be desirable, please let me know.

Sincerely yours,

RSKirkland

Robert S. Kirkland
Associate Director
Nuclear Research Center

RSK/jlr

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Georgia Institute of Technology*

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

   Roughly estimate approximately $200,000 for LEU fuel plus approximately epual amount for SAR preparations reloading and startup testing.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

   Based on Michigan experience, not much effect is expected (approximately 10%), but studies will be required.

   c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

   Specific activities for short-lived isotopes would be decreased undesirably.

   d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Plese consider costs of decommissioning if applicable.

   Any significant expense would lead to reactor shutdown. Technical assistance with SAR revision would be required.

   e. What would be the net cost/benefit of conversion of your reactor to LEU?

   Expect ratio to be high.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Georgia Institute of Technology*

2. Licensing

   a. Safety-related technical problems, if any.

      None anticipated.

   b. Man-month requirements for SAR preparation and defense.

      3-6 months assuming no fuel geometry changes.

   c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

      None anticipated.

   d. Problems related to additional hearings and other processes, if any.

      Please refer to UCLA experience.

   e. Would a NUREG licensing guide be useful to you?

      A model licensing application containing answers would be more helpful than a detailed guide. In any event, it should be limited to LEU conversion.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Georgia Institute of Technology*

3. Feasibility

The NRC "Statement of Policy," August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs." Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

Even if critcability is possible, reactivity will be so low that fuel lifetime will be too short (excessive fuel costs, refueling time, radiation exposure during refueling, shipping costs, etc.) and that experiments will be limited.

b. Based on use of advanced fuels once these are demonstrated and available?

No impact other than flux reduction mentioned earlier.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Georgia Institute of Technology*

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?
Unirridiated : < 5 kg
Irridaited : 4 kg

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?
Present inventory sufficient so that new fuel will not be required for several years.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.
No refueling is scheduled for purposes of adding reactivity.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?
Would phase in LEU during refuelings to increase reactivity (refer to 4c).

e. Calendar time to prepare SAR and license modifications.
6-12 months.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.
12-18 months.

g. Calendar time to plan and effect engineering changes, if any.
None anticipated.

h. Calendar time to carry out additional LEU-related start tests.
A few man-months spread out over many years.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.
With present schedule full burnup will not be achieved for several years.

j. How long afterward could you ship your last HEU fuel?
6 months.

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RHODE ISLAND ATOMIC ENERGY COMMISSION
Nuclear Science Center
South Ferry Road
Narragansett, R. I. 02882

September 8, 1983

Dr. Donald R. Harris
Dept. of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, N. Y. 12181

Dear Dr. Harris:

The following information is submitted in response to your letter concerning the use of LEU in the R. I. Nuclear Science Center Reactor. The information assumes that we are allowed to utilize the existing unused 44 HEU fuel elements and that we are allowed to intermix HEU and LEU elements in a core. We are also drawing heavily on the University of Michigan experience in formulating our response. Because we are only now beginning to prepare a SAR, our responses are necessarily preliminary. Our responses are keyed to the questions in your letter.

1. Functional Impacts

   a.) The costs of conversion to LEU are associated with the preparation and defense of the SAR. We estimate that we will require about 3 man-months to complete the SAR. We cannot estimate the time required by NRC for review.

   We do not expect increased costs because of LEU for fuel shipments, revised fuel cycle, revised functional optimization or loss of revenue during conversion.

   We see no operational benefits from conversion to LEU. Whether there will be benefits for safeguard and security schemes for facilities possessing more than a trigger amount of HEU will only be known following the promulgation of the safeguards contingency plan presently being developed by NRC.

   b.) No significant effects.

   c.) No significant effects.

   d.) We expect that we will be required to convert to LEU.

Since we are already a participant in the DOE fuel cycle assistance program, we expect LEU fuel to be provided to us. If sophisticated thermo hydraulic calculation become necessary, we would expect assistance from the support group at Argonne National Laboratory.

c.) The costs are those associated with preparation and defense of the SAR. The only benefits are those which may come from reduced safeguards/security requirements.

2. Licensing

a.) Based on the University of Michigan experience, we do not expect safety related technical problems.

b.) Three man-months (spread over at least six months) would be required for SAR preparation. We cannot estimate the time required for NRC review.

c.) We do not expect licensing problems. Our fuel is owned by DOE and we expect DOE to accept the return of LEU spent fuel including its plutonium content.

d.) We would not expect hearings or other public processes as part of the SAR review process.

e.) A NUREG licensing guide would be useful.

3. Feasibility

a.) Conversion to LEU is feasible based on the use of fuels fabricated with existing technology.

4. Scheduling

a.) We presently have 31 spent elements awaiting shipment to reprocessing.

We presently have 30 elements in use with various percent burnup.

We presently have 6 unused elements at this facility and an additional 38 stored at a DOE facility.

We presently have approximately 7660 grams of uranium in the facility.

b.) Our core does not last a lifetime. Under the DOE fuel cycle assistance program we expect new fuel fabrication for us to begin in FY 84. (That is after October of 84.) We do not batch reload but instead add new fuel one ele- at a time. We expect the existing HEU fuel to last at least two years (to late 1985).

c.) Using HEU uranium has required about 40 fuel elements every two years. This has been possible by increasing core size when elements have significant burnup. For this, we accept a decrease in flux. Since LEU will in itself cause a decrease in flux, we may not operate with increased core size. Therefore, the use of LEU would require about 45 elements every two years.

d.) Based on the Michigan experience, LEU and HEU fuel are indistinguishable from an operational standpoint. We would hopefully phase in LEU fuel elements as required by burnup.

e.) At least 6 months calendar time would be required for preparation of SAR.

f.) At least three months calendar time would be required to prepare LEU fuel specifications. We are on the DOE - B&W fuel fabrication schedule for 1985.

g.) No engineering changes are required.

h.) Assuming that the University of Michigan results are applicable here, we would expect not more than two months of LEU related start tests.

i.) The HEU fuel on hand will last a minimum of two years.

j.) Three months.

We will be pleased to provide additional information if required.

Very truly yours,

A. Francis DiMeglio
Director

AFD:ag

THE UNIVERSITY OF MICHIGAN
PHOENIX MEMORIAL LABORATORY
FORD NUCLEAR REACTOR
ANN ARBOR, MICHIGAN 48109
(313) 764-6220

September 7, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Dr. Harris:

This letter is in response to your request for responses to items concerning the effects of LEU conversion on the Ford Nuclear Reactor.

The Ford Nuclear Reactor (FNR) converted to LEU fuel in December, 1981 utilizing a direct fuel meat substitution of 42 weight percent, 19.5% enriched uranium for 14.7 weight percent, 93% enriched uranium. A meat thickness increase of 50% was accommodated by a clad thickness decrease of 25%. No alteration in coolant channel dimensions or changes in the thermal hydraulic characteristics of the core were required. The conversion has resulted in a slight hardening of core flux and a 5 - 10% decrease in thermal leakage flux. Impact on reactor operations and scheduling has been minimal. Core physics analysis costs and man-hours were inordinately high because the FNR served as an LEU conversion prototype. The single largest dollar cost to the facility will be about $50,000 for two HEU spent fuel shipments that would not otherwise have been required.

1. Functional Impacts

   a. Costs

	Man-hours	Dollars
Initial program planning	120	0
License amendment and safety analysis	600	5,000
Core physics calculations	4,000	10,000
LEU fuel	200	0
Training	80	0
HEU fuel	80	50,000
Verification of LEU fuel	320	10,000

   b. Effects

   In core flux hardened. Ex core thermal flux decreased 5 - 10%. Negligible effects on functional capability.

   c. None

   d. Converted to LEU fuel.

   e. Cost/Benefits

   Reduction in security class from "moderate" to "low" strategic quantities when HEU shipped off site. We anticipate a somewhat increased fuel element burnup and lifetime with LEU fuel.

2. Licensing
   a. None
   b. SAR preparation and defense -- 600 man hours or about 4 man months.
   c. None
   d. None. No fuel redesign or facility modifications required. Minor license amendment with no public hearing.
   e. Yes.
3. Feasibility
   a. No
   b. Not applicable.
4. Scheduling
   a. Irradiated HEU fuel - 7097 gm U235
      Fresh HEU fuel - 2,750 gm U235
      To be delivered - 140 gm U235 (1 element)
   b. No. Next fuel delivery is scheduled for March, 1984 and will be LEU.
   c. Approximately 18 fresh elements are utilized per year. Fresh elements are cycled into the core to replace expended elements at a rate of 1-2 per month.
   d. Fuel conversion had been planned as a gradual replacement, but the test program forced a full core replacement.
   e. SAR preparation and submittal - 7 months.
   f. LEU fuel specifications and procurement - 19 months.
   g. No engineering changes required.
   h. LEU tests and verification - 5 months. Actual time needed for critical experiment and basic physics measurements during which the core was not available - 6 weeks. During the remaining measurements, the core was fully available for use.
   i. Remaining HEU is 20, 10-plate elements for which there is no planned use.
   j. Last HEU fuel will probably be shipped in the spring of 1985. Two initial shipments are planned for the spring of 1984.

Sincerely,

Reed R. Burn

Reed R. Burn, Manager
Ford Nuclear Reactor

RRB/wp

UNIVERSITY OF VIRGINIA
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
CHARLOTTESVILLE, 22901

DEPARTMENT OF NUCLEAR ENGINEERING AND ENGINEERING PHYSICS
REACTOR FACILITY

September 12, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Don:

Our position on LEU fuel has been that a conversion to LEU will not make any significant difference in our operation as long as the federal government will continue its fuel support program and if the NRC will accept generic safety analysis reports. I recognize that this involves two very large assumptions

1) That the federal government will continue its fuel assistance program. At present we do not have to pay for the fuel and are only paying spent fuel shipment costs. We presume that this policy will continue with LEU fuel. We also presume that the quantity of LEU fuel will be sufficient for a smooth transition, i.e. for flexibility in operation we require more than the minimum number of fuel elements to make a single core.

2) The second major assumption is that the NRC will accept generic SAR's. If they do this then we believe we can use the work already done at the University of Michigan in our licensing applications. If so, the time and effort on our staff to effect the change would not be significant. If the NRC will not accept a generic SAR then our effort would have to be the same as that already expended by the University of Michigan, and Bob Burn can supply cost estimates.

Our response to your questions is colored by the above assumptions.

1) Functional Impact
Under the above assumptions the cost would probably be equivalent to two man-years of effort or approximately $100,000. This is an out of the air guess and could be low by a factor of 5. We have not studied the effect of changed technical performance of our reactor but have been led to believe that they would be minimal. Changes in neutron flux levels of less than 10-20% would not have a major effect upon our revenue. We don't really know enough about an LEU core to make an intelligent reply to this question. For example, much of our work involves fast neutron irradiations. If we converted to an LEU core with the same thermal neutron

population, would the fast neutron flux at our irradiation facilities be the same? If the fast neutron flux is degrated by more than 10% then there would be a major effect on our revenue.

2) Licensing
The effort would be minimum if we were provided with an SAR based on work done at the University of Michigan. A new NUREG licensing guide would not be as useful as generic licensing. If the reactor parameters of importance to our work are degraded and we need to increase power to recover these characteristics, relicensing would be a major job.

3) Feasibility
I presume the key phrase here is "will not significantly affect reactor performance." As long as the changes in reactor parameters are on the order of 10% or less I see no effect upon our operation.

4) Scheduling
   a) We presently have about 12 kg of HEU fuel
   b) Our UVAR core will not last for the life time of the facility. We have a fuel delivery scheduled for fall 1983 and are now operating on a two year refueling cycle. However we also operate a low power training reactor, the CAVALIER. The fuel for this reactor will last the lifetime of the facility and would have to be replaced on an LEU conversion.
   c) If the performance is not significantly altered I would expect to maintain a similar refueling schedule with LEU fuel.
   d) We would schedule a transition to LEU fuel during one of our regular refueling periods.
   e,f,g,h) If we can use a generic analysis of fuel characteristics the calendar time to effect these changes should be of the order of 6 months. Our present HEU fuel should last through 1987.

TGWilliamson
T.G. Williamson, Chairman
Department of Nuclear Engineering
and Engineering Physics

J.S. Brenizer
J. S. Brenizer, Director
UVa Reactor Facility

TGW/JSB:ph

University of Lowell
One University Avenue
Lowell, Massachusetts 01854
(617) 452-5000

October 26, 1983

Mr. Thomas J. Wallace
Radiation Laboratory
University of Lowell
One University Avenue
Lowell, MA 01854
452-5000 ext. 2232

Dr. Donald Harris
LEU Study Group
Dept. of Nuclear Engineering
Rennselaer Polytechnic Institute
Troy, NY 12181

Dear Dr. Harris:

In response to your letter of August 29, the University of Lowell is supplying the answers to your questions. In general, Lowell does not see a serious impact on our operations resulting from conversion to LEU Fuel and in fact may reduce some requirements. Specific answers to your questions are as follows:

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

      It is almost impossible to give a realistic number but if I must guess, I would say $30,000 to $50,000.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

      Unknown. Negligible expected.

c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

None.

d. What would your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Please consider costs of decommissioning if applicable.

If funds were provided, no effect.

e. What would be the net cost/benefit of conversion of your reactor to LEU?

None.

2. Licensing

a. Safety-related technical problems, if any.

None.

b. Man-month requirements for SAR preparation and defense.

Three man-months.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

None.

d. Problems related to additional hearings and other processes, if any.

None. Minor amendment.

e. Would a NUREG licensing guide be useful to you?

Yes.

3. Feasibility

The NRC "Statement of Policy", August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs". Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

No.

b. Based on use of advanced fuels once these are demonstrated and available?

Not applicable.

4. Scheduling

a. How many grams of unirradiated/irradiated HEU fuel have you on hand?

Unirradiated < 1 kg 4000 gm total
Irradiated ~ 3 kg

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?

No. Twelve elements in storage at B&W.
1984 sometime.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.

One element/mo.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?

Rotating element replacement, one for one.

e. Calendar time to prepare SAR and license modifications.

One to one and a half years.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.

Three months.

g. Calendar time to plan and effect engineering changes, if any.

Not applicable.

h. Calendar time to carry out additional LEU-related start tests.

Three to six months.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.

Last HEU insertion - five years.
Four year core residence time.

j. How long afterward could you ship your last HEU fuel?

∼ ten years.

If there are any additional questions please let me know.

Sincerely yours,

Thomas Wallace

Thomas J. Wallace
Nuclear Reactor Supervisor

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Lowell*

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

      $20,000.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

      Unknown. Negligible expected.

   c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

      None.

   d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Plese consider costs of decommissioning if applicable.

      If funds were provided, no effect.

   e. What would be the net cost/benefit of conversion of your reactor to LEU?

      None.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Lowell*

2. Licensing

a. Safety-related technical problems, if any.

None.

b. Man-month requirements for SAR preparation and defense.

3 man-months.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

None.

d. Problems related to additional hearings and other processes, if any.

None.

Minor amendment.

e. Would a NUREG licensing guide be useful to you?

Yes.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Lowell*

3. Feasibility

The NRC "Statement of Policy," August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs." Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

No.

b. Based on use of advanced fuels once these are demonstrated and available?

Not applicable.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Lowell*

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?
Unirradiated: <1 kg 4000 gm total.
Irradiated: approximately 3 kg.

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?
No. 12 elements in storage at B&W. 1984 sometime.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.
1 element/month.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?
Rotating element replacement, 1 for 1.

e. Calendar time to prepare SAR and license modifications.
1-1/2 years.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.
3 months.

g. Calendar time to plan and effect engineering changes, if any.
Not applicable.

h. Calendar time to carry out additional LEU-related start tests.
3-6 months.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.
Last HEU insertion approximately 5 years.
4 year core residence time.

j. How long afterward could you ship your last HEU fuel?
Approximately 10 years.

UNIVERSITY OF MISSOURI-ROLLA

Nuclear Reactor Facility
Nuclear Reactor
Rolla, Missouri 65401
Telephone: (314) 341-4236

September 7, 1983

Dr. Donald R. Harris
Chairman LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Dr. Harris:

Enclosed are our responses to the questions your committee posed regarding conversion of our reactor to LEU fuel. Also enclosed is a brief position summary on the matter.

Sincerely,

Albert E. Bolon

Albert E. Bolon, SO
Reactor Director

Enclosure

Responses to Questions Posed by Low Enrichment Study Group

POSITION SUMMARY

The management of the UMR Reactor is in favor of converting from High-Enriched Uranium (HEU) fuel to Low-Enriched Uranium (LEU) fuel and believe that such a conversion would be a positive net benefit provided that the NRC lessens some of the physical security, emergency preparedness and operator licensing requirements they now impose and provided that the federal government pays for all reasonable expenses of such a conversion.

University of Missouri-Rolla
Nuclear Reactor Facility
Rolla, Missouri 65401

1. Functional Impacts

   a. The cost of LEU fuel for the UMR Reactor is estimated to be approximately $630,000. Standard TRIGA fuel elements (20% enrichment) could be used after some modifications to their nose pieces were made. Costs for those modifications are estimated to be $40,000. The cost for SAR preparation and its defense is estimated to be $90,000. Loss of revenue due to the conversion to LEU fuel could be as high as $80,000.

      Summarizing all above items total costs of the LEU conversion at the UMR Reactor amount to $840,000.

   b. At this stage of study, it is difficult to predict the effect of LEU conversion on neutron flux level and spectrum in detail. Our grid plate has 54 holes in which to place nose pieces of fuel elements. Currently, with HEU fuel we just use 21 of them. There should be not functional difficulty of accommodating a critical mass of LEU fuel.

   c. Conversion to LEU would not adversely affect our current education and training programs. However, should the technical reactor performance be downgraded (e.g. lower neutron flux output) this would result in loss of revenue from research and irradiation contracts possibly as high as $20,000 per year.

   d. Since there are infinitely many alternatives for government financial support, we will give our opinions on the two extremes. If the federal government were to provide no support, and there is any significant cost to the University (say $10K or more), it is most likely the campus administration will shut the facility down and decommission it. If the federal government were to pay all reasonable expenses, including SAR preparation and licensing, we would gladly convert from HEU to LEU fuel asap.

   e. The net cost/benefit of converting the UMR Reactor to LEU fuel (if it did not cost the University anything to do it) would be a positive benefit provided that the NRC also lessens some of the physical security, emergency preparedness and operator licensing requirements they now impose.

2. Licensing

   a. There are no apparent unresolved safety problems involved in a complete conversion of HEU to LEU fuel.

   b. Although this can only be an estimate, we would anticipate 36 man-months for SAR preparation and defense.

   c. Obviously much more plutonium is going to be produced in LEU fuel (where the initial U-238 is 80%) than in HEU fuel (where the initial U-238 is only 10% -- in our case).

   d. If the NRC is the prime moving source behind requiring such conversions, they should also have the authority to provide relief from burdensome licensing, including public hearings. For example, they could conduct a generic rule-making hearing on the matter.

   e. If we are required to write any new licensing documents, proper NRC guides (applicable to training, research and test reactors) would be in order.

3. Feasibility

   a. TRIGA-type fuel based on existing technology is sufficient.

   b. Advanced fuel materials or designs would not be needed.

4. Scheduling

   a. We currently have 4780 grams of irradiated HEU fuel on hand and no unirradiated HEU fuel.

   b. Our current core should last the reactor's lifetime based on the current rate of burnup, etc.

   c. NA

   d. We would plan to do it over the summer months, unless it would interfere with a utility company operator training program.

   e. We would estimate it would take a calendar year to prepare a SAR and other licensing documents.

   f. It would probably take twelve months to prepare fuel specs, drawings etc. and acquire new fuel.

   g. It would probably take six months to make any engineering changes. (These could be concurrent with 4.f.).

   h. LEU startup tests would take about three months after fuel loading by an approach to critical method.

   i. See response 4.b.

   j. NA

OSU

The Ohio State University

Nuclear Reactor Laboratory
1298 Kinnear Road
Columbus, Ohio 43212
Phone 614 422-6755

October 27, 1983

Dr. Donald R. Harris
Chairman, LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Professor Harris:

Enclosed with this letter is the completed survey form for the LEU conversion study. I hope you will find it useful in the overall analysis of the feasibility of converting lower-power NRPs to the LEU fuel.

Our primary concerns with LEU conversion of the OSURR are economic. I do not foresee any possibility of continued operation of our facility unless most, if not all, of the costs associated with LEU conversion are borne by an outside agency. However, this is my personal opinion only and should not be taken as a statement of policy of the University or its agencies.

An additional concern is the impact on performance characteristics. As you might guess, at 10 kilowatts thermal power, the thermal neutron flux in our various irradiation facilities is not that great (perhaps on the order of 10^{11} nv), so any further reduction in the flux is a problem. We also have some experiments wherein further contamination of the flux by fast neutrons would be of concern. I have suggested that the loss in thermal flux might be partially offset by coupling LEU conversion with an increase in the power of facilities such as the OSURR.

Thank you for allowing us the opportunity to participate in this survey. Please contact me should you or any of your associates in the study group have questions or require further information. Best wishes for success in your study.

Sincerely,

Joseph W. Talnagi Jr.

Joseph W. Talnagi, Jr.
Research Associate

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Ohio State University

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.
   Assuming no government cost-sharing about $750,000.00 to convert. No foreseeable cost benefits unless conversion is coupled with a power increase. This includes fuel costs.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.
   Expect about 10% thermal neutron flux reduction overall, with general "hardening" of the neutron energy spectrum.

   c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?
   Loss of thermal flux will affect activation analysis sensitivity. Will also affect some biological materials irradiation experiments currently in progress (neutron irradiation of in-vitro tumor cells).

   d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Please consider costs of decommissioning if applicable.
   Without almost total goverment funding of conversion, coupled with a power increase, the most likely decision will be decommissioning of the facility.

   e. What would be the net cost/benefit of conversion of your reactor to LEU?
   Costs would be high, benefits low unless coupled with a power increase.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Ohio State University

2. Licensing

a. Safety-related technical problems, if any.
Probably none, if fuel specified has been shown to be licensable.

b. Man-month requirements for SAR preparation and defense.

About 6-9 person-months.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

None, if lifetime core status can be maintained.

d. Problems related to additional hearings and other processes, if any.

Costs associated with such litagation.

e. Would a NUREG licensing guide be useful to you?

If it were of sufficient detail to provide necessary details of conversion process.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Ohio State University

3. Feasibility

The NRC "Statement of Policy", August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs". Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

Fuels specified should have been demonstrated to be licensable and should also be compatible with existing reactor core structures (i.e., control rod assemblies, fuel assembly grid plate).

b. Based on use of advanced fuels once these are demonstrated and available?

As noted above.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Ohio State University

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?

Consider all to be irradiated to various degrees. License limit is 4.6 kg. About 3565.0 grams are currently on-site.

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?

Lifetime Core - however, SAR specifies fuel assembly lifetime is 6-8 years. Current burnup is low - about 0.5-1.0 gram total over 21 years of operation. Difficult to predict continued fuel viability.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.

N/A since refueling is not done.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?

Complete core change, preferably during a time of reduced facility utilization to minimize user impacts.

e. Calendar time to prepare SAR and license modifications.

About 12-18 months.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.

N/A since we are assuming available, compatible LEU fuel.

g. Calendar time to plan and effect engineering changes, if any.

Perhaps 3 months - expect minimal impacts if assume compatible fuel is available.

h. Calendar time to carry out additional LEU-related start tests.

Perhaps 6 months.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.

N/A - lifetime core.

j. How long afterward could you ship your last HEU fuel?

About 3-6 months after complete core conversion and testing of LEU core.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Ohio State University*

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

   5000 man-hours, $100,000, lost down time. Reduced security, no specific costs.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

   Loss of 10% thermal flux. Reoptimize spectrum in irradiation facilities.

   c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

   None.

   d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Plese consider costs of decommissioning if applicable.

   Staff man-hour funding required. Cutback on current projects. University would probably decommission without support.

   e. What would be the net cost/benefit of conversion of your reactor to LEU?

   No benefit.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Ohio State University*

2. Licensing

a. Safety-related technical problems, if any.

None.

b. Man-month requirements for SAR preparation and defense.

6 months.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

None.

d. Problems related to additional hearings and other processes, if any.

None.

e. Would a NUREG licensing guide be useful to you?

Yes. If adequately detailed.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Ohio State University*

3. Feasibility

The NRC "Statement of Policy," August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs." Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

No.

b. Based on use of advanced fuels once these are demonstrated and available?

Not required.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Ohio State University*

4. Scheduling

   a. How may grams of unirradiated/irradiated HEU fuel have you on hand?
   All irradiated 4.6 kg.

   b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?
   Yes, barring corrosion failure.

   c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.
   Not applicable.

   d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?
   Full core conversion in summer.

   e. Calendar time to prepare SAR and license modifications.
   6-9 months. 12 months max.

   f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.
   Unknown.

   g. Calendar time to plan and effect engineering changes, if any.
   None.

   h. Calendar time to carry out additional LEU-related start tests.
   3 months.

   i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.
   Lifetime core.

   j. How long afterward could you ship your last HEU fuel?
   3 months.

THE UNIVERSITY OF KANSAS · LAWRENCE, KANSAS · 66044
DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING

Chemical Engineering
102 Nuclear Reactor Center
913-UN 4-3938

October 13, 1983

Dr. Donald Harris
Dept. of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Don:

Here are the answers to your survey.

1a Unknown.
1b Unknown.
1c No impact.
1d Unknown. The University would probably decommission rather than go through conversion.
1e Cost - probable reactor shutdown
Benefit - none apparent

2a None.
2b 3.
2c None.
2d 1980 license renewal application still being considered. One intervenor was not within the time limit.
2e Probably.

3a No.
3b Not applicable.

4a 2 fresh elements, 333 g U-235
16 elements in core 2439 g U-235
4b Yes.
4c Not applicable
4d Over the summer
4e 1 year.
4f Unknown.
4g Not applicable.
4h 3 months.
4i Lifetime core
4j Within one year. Current license permits only a formula quantity.

Robert Burns at Michigan was helpful in supplying these answers.

Very truly yours,

Russell Mesler

Russell B. Mesler
Professor

RBM:dm

cc: Robert Burns

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Kansas*

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

   Unknown.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

   Unknown.

   c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

   No impact.

   d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Plese consider costs of decommissioning if applicable.

   Unknown. The university would probably decommission the reactor rather than go through conversion.

   e. What would be the net cost/benefit of conversion of your reactor to LEU?

   Cost - probable reactor shutdown.
   Benefit - nonapparent.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Kansas*

2. Licensing

   a. Safety-related technical problems, if any.

   None.

   b. Man-month requirements for SAR preparation and defense.

   3.

   c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

   None.

   d. Problems related to additional hearings and other processes, if any.

   1980 license renewal application still in progress. One intervenor attempt was not within time limit of license renewal.

   e. Would a NUREG licensing guide be useful to you?

   Possible.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Kansas*

3. Feasibility

The NRC "Statement of Policy," August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs." Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

No.

b. Based on use of advanced fuels once these are demonstrated and available?

Not applicable.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *University of Kansas*

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?
2 elements unirradiated - 33 gm U255.
16 in core elements (145 plates) - 2439 gm U235.

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?
Yes.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.
N/A

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?
Full core conversion over summer months of year scheduled.

e. Calendar time to prepare SAR and license modifications.
1 year.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.
Unknown.

g. Calendar time to plan and effect engineering changes, if any.
N/A

h. Calendar time to carry out additional LEU-related start tests.
3 months.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.
Lifetime core.

j. How long afterward could you ship your last HEU fuel?
Within one year. Current license permits only a formula quantity on site.

LESLIE C. WILBUR
PROFESSOR OF MECHANICAL ENGINEERING
DIRECTOR, NUCLEAR REACTOR FACILITY
Worcester Polytechnic Institute
Worcester, Massachusetts 01609

Registered Professional Engineer
Commonwealth of Massachusetts
PE 8196

Business 617-793-5688
Residence 617-838-2553

September 1, 1983

Dr. Donald R. Harris
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Dr. Harris:

This is a hasty response to your letter of August 29 in an effort to meet your September 9 deadline. I believe I can summarize my personal estimate of the LEU conversion as follows:

1. Our present fuel is expected to last the lifetime of the reactor. Our license was recently renewed for 20 years.
2. We could probably use LEU without major problems and our program, which is entirely educational in nature, would be unaffected.
3. Any substantial cost to WPI for the conversion would almost surely result in our terminating our reactor program and decommissioning the reactor. We have given very serious consideration to decommissioning, and at the moment have an uneasy truce with our administration which permits us to continue in operation. As I understand our president's position, he favors nuclear power but believes facilities such as the nuclear reactor should be funded by industry or the government, not by private colleges, given the status of nuclear power today. He suspects decommissioning costs can only increase, and is therefore quite willing to spend substantial sums now to decommission, but not to perpetuate the reactor.

These are my personal observations and conclusions expressed as an individual, not as a spokesman for WPI.

Sincerely,

Les Wilbur

L. C. Wilbur, Professor of
Mechanical Engineering
and
Director, Nuclear Reactor Facility

LCW:ama

cc: Prof. D. N. Zwiep

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Purdue University*

1. Functional Impacts

   a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

      Unknown.

   b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

      Unknown.

   c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

      No effect.

   d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Plese consider costs of decommissioning if applicable.

      Conversion acceptable if cost borne by DOE. Prefer not.

   e. What would be the net cost/benefit of conversion of your reactor to LEU?

      Unknown.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Purdue University*

2. Licensing

a. Safety-related technical problems, if any.

No.

b. Man-month requirements for SAR preparation and defense.

Unknown.

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

None. Normal cooldown before shipment.

d. Problems related to additional hearings and other processes, if any.

None.

e. Would a NUREG licensing guide be useful to you?

Yes.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Purdue University*

3. Feasibility

The NRC "Statement of Policy," August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycie costs." Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

No.

b. Based on use of advanced fuels once these are demonstrated and available?

Not applicable.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: *Purdue University*

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?
Unirradiated - 200 gm.
Irradiated - 1900 gm.

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?
Yes.

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.
N/A

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?
Full core conversion.

e. Calendar time to prepare SAR and license modifications.
6 months.

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.
Unknown.

g. Calendar time to plan and effect engineering changes, if any.
N/A

h. Calendar time to carry out additional LEU-related start tests.
2 months.

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.
Lifetime core.

j. How long afterward could you ship your last HEU fuel?
Unknown. Approximately 3 months.

Rensselaer Polytechnic Institute Troy, New York 12181

September 14, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Sir,

The RPI Critical Facility responses to the LEU Study Group Inquiry (D. R. Harris to directors of university reactors with HEU fuel, August 29, 1983) are as follows.

1. Functional Impacts

   a. The costs of fuels and of fuel transportation have been provided in the past by the U.S.D.O.E. for the RPI reactor, and it is anticipated that this situation will apply to LEU fuel. The additional costs associated with fuel design, core design, fuel procurement, fuel transportation, core installation, engineering modifications, core measurements, revised SAR, and license amendment are estimated to be two staff man-years or about $100,000. A potential benefit might be reduced concern for terrorist activity.

   b. The functional capability of the core would be unchanged by conversion to LEU.

   c. There would be no significant LEU impact on RPI programs.

   d. If the university were reimbursed for all or most of the costs under 1.a. above, then LEU conversion would probably be undertaken.

   e. The cost of reactor decommissioning would be to detract from the training of nuclear engineers at RPI. For many years the critical facility course has been identified by nuclear engineering graduates to be their most valuable course. Elimination of this training service would not be in the national interest.

2. Licensing

   a. There could be a safety-related gain in that LEU fuel would have a prompt negative temperature coefficient. In addition, we would hope to improve the fuel plate spacers in the fuel assemblies.

   b. Seven.

   c. None.

   d. Current license renewal still in progress.

   e. Yes.

3. Feasibility

   a. None.

   b. Not applicable.

4. Scheduling

   a. 4980.34 gm U235 essentially unirradiated.

   b. Yes.

   c. Not applicable.

   d. The transition to LEU fuel could proceed at the pace of the tasks in 1.a. above. New LEU fuel could be installed about one month after its arrival. The entire process, from fuel design to approved license amendment could require several years.

   e. Six months.

   f. Several months.

   g. Several months.

   h. Six months.

i. Not applicable.

j. Immediately.

Sincerely,

Frank Wicks

Dr. Frank Wicks, Supervisor
RPI Critical Facility

D. R. Harris

Dr. D. R. Harris, Director
RPI Critical Facility

UNIVERSITY OF VIRGINIA
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
CHARLOTTESVILLE, 22901

DEPARTMENT OF NUCLEAR ENGINEERING AND ENGINEERING PHYSICS
REACTOR FACILITY

September 12, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Don:

Our position on LEU fuel has been that a conversion to LEU will not make any significant difference in our operation as long as the federal government will continue its fuel support program and if the NRC will accept generic safety analysis reports. I recognize that this involves two very large assumptions

1) That the federal government will continue its fuel assistance program. At present we do not have to pay for the fuel and are only paying spent fuel shipment costs. We presume that this policy will continue with LEU fuel. We also presume that the quantity of LEU fuel will be sufficient for a smooth transition, i.e. for flexibility in operation we require more than the minimum number of fuel elements to make a single core.

2) The second major assumption is that the NRC will accept generic SAR's. If they do this then we believe we can use the work already done at the University of Michigan in our licensing applications. If so, the time and effort on our staff to effect the change would not be significant. If the NRC will not accept a generic SAR then our effort would have to be the same as that already expended by the University of Michigan, and Bob Burn can supply cost estimates.

Our response to your questions is colored by the above assumptions.

1) Functional Impact
Under the above assumptions the cost would probably be equivalent to two man-years of effort or approximately \$100,000. This is an out of the air guess and could be low by a factor of 5. We have not studied the effect of changed technical performance of our reactor but have been led to believe that they would be minimal. Changes in neutron flux levels of less than 10-20% would not have a major effect upon our revenue. We don't really know enough about an LEU core to make an intelligent reply to this question. For example, much of our work involves fast neutron irradiations. If we converted to an LEU core with the same thermal neutron

population, would the fast neutron flux at our irradiation facilities be the same? If the fast neutron flux is degrated by more than 10% then there would be a major effect on our revenue.

2) Licensing
The effort would be minimum if we were provided with an SAR based on work done at the University of Michigan. A new NUREG licensing guide would not be as useful as generic licensing. If the reactor parameters of importance to our work are degraded and we need to increase power to recover these characteristics, relicensing would be a major job.

3) Feasibility
I presume the key phrase here is "will not significantly affect reactor performance." As long as the changes in reactor parameters are on the order of 10% or less I see no effect upon our operation.

4) Scheduling
a) We presently have about 12 kg of HEU fuel
b) Our UVAR core will not last for the life time of the facility. We have a fuel delivery scheduled for fall 1983 and are now operating on a two year refueling cycle. However we also operate a low power training reactor, the CAVALIER. The fuel for this reactor will last the lifetime of the facility and would have to be replaced on an LEU conversion.
c) If the performance is not significantly altered I would expect to maintain a similar refueling schedule with LEU fuel.
d) We would schedule a transition to LEU fuel during one of our regular refueling periods.
e,f,g,h) If we can use a generic analysis of fuel characteristics the calendar time to effect these changes should be of the order of 6 months. Our present HEU fuel should last through 1987.

T.G. Williamson, Chairman
Department of Nuclear Engineering
and Engineering Physics

J. S. Brenizer, Director
UVa Reactor Facility

TGW/JSB:ph

Manhattan College

MANHATTAN COLLEGE PARKWAY
RIVERDALE, NEW YORK 10471
(212) 920-0145

MECHANICAL ENGINEERING DEPARTMENT

September 29, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, N. Y. 12181

Dear Dr. Harris:

Dr. Ronald Kane, Chairman of our Mechanical Engineering Department, has asked me to reply to your letter concerning the possible conversion of research test and training reactors to the use of fuel with no greater than 20 % enrichment.

As you may already know, our reactor is for teaching purposes only and operates at a maximum power allowed by the NRC of only 0.1 watt. Considering this fact, most of the questions you have raised are either too difficult or impossible to answer.

Consequently I hope that you will be satisfied with a simple expression of my sentiments on this matter. I have already expressed these sentiments to Dr. Richard T. Leahy, Jr., the Chairman of your Department, in a letter dated April 14, a copy of which is enclosed.

Sincerely,

Brother Gabriel Kane

Brother Gabriel Kane
Chief Reactor Supervisor

BGK/w
enc

cc: Dr. Ronald Kane

Manhattan College

MANHATTAN COLLEGE PARKWAY
BRONX, NEW YORK 10471
(212) [illegible]
920-0145

MECHANICAL ENGINEERING DEPARTMENT

April 14, 1983

Dr. Richard T. Lahey, Jr.
Chairman
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, N.Y. - 12181

Dear Dr. Lahey:

As I explained to you over the phone, Dr. Ronald S. Kane, the Chairman of our Mechanical Engineering Department, received a copy of your letter referring to proposed NRC legislation to limit all research reactors to fuel with no greater than 20% enrichment. Dr. Kane has asked me to reply to this letter.

I have enclosed a very brief description of our reactor so that you may be able to understand my comments.

Naturally, I am most strenuously opposed to any such legislation. Considered from the viewpoint of our reactor, it would serve no useful purpose and because of the conversion to the lower enrichment, make it extremely difficult if not impossible to attain criticality.

The apparent purpose of the proposed legislation is to prevent anyone from making an atom bomb by using highly enriched uranium. But how could sufficiently pure uranium be extracted from an alloy of uranium and aluminum, clad in alumninu?

Your letter states that " Dr. Ross indicated that DOE may be willing to pick up the cost of any new low enrichment required if this proposed new requirement was implemented. " However, even if DOE supplies sufficient funds, how can fuel elements with only 20% enrichment replace fuel elements with 92% enrichment? As shown on the accompanying diagram, we have room for only 31 fuel elements on our grid plate. It seems hardly likely that it would be possible to attain criticality with 31 fuel elements with 20% enrichment, where presently criticality is reached with 15 full fuel elements and one partial fuel element with 92% enrichment.

I trust that my comments may be of some assistance to your committee.

Sincerely,

Brother Gabriel Kane, FSC, Ph. D.
Senior Reactor Operator

BGK/w
enc
cc: Dr. Ronald S. Kane

Manhattan College

MANHATTAN COLLEGE PARKWAY
BRONX, NEW YORK 10471
(212) 920-0145

MECHANICAL ENGINEERING DEPARTMENT

MANHATTAN COLLEGE ZERO POWER REACTOR

The Manhattan College Zero Power Reactor (MCZPR) is a heterogeneous, pool-type using solid 92 percent enriched uranium fuel and is moderated by light water. The principal components of the reactor are the reactor vessel and its associated equipment, the control system, and the demineralizer system. The maximum allowed power level by the Nuclear Regulatory Commission is 100 milliwatts.

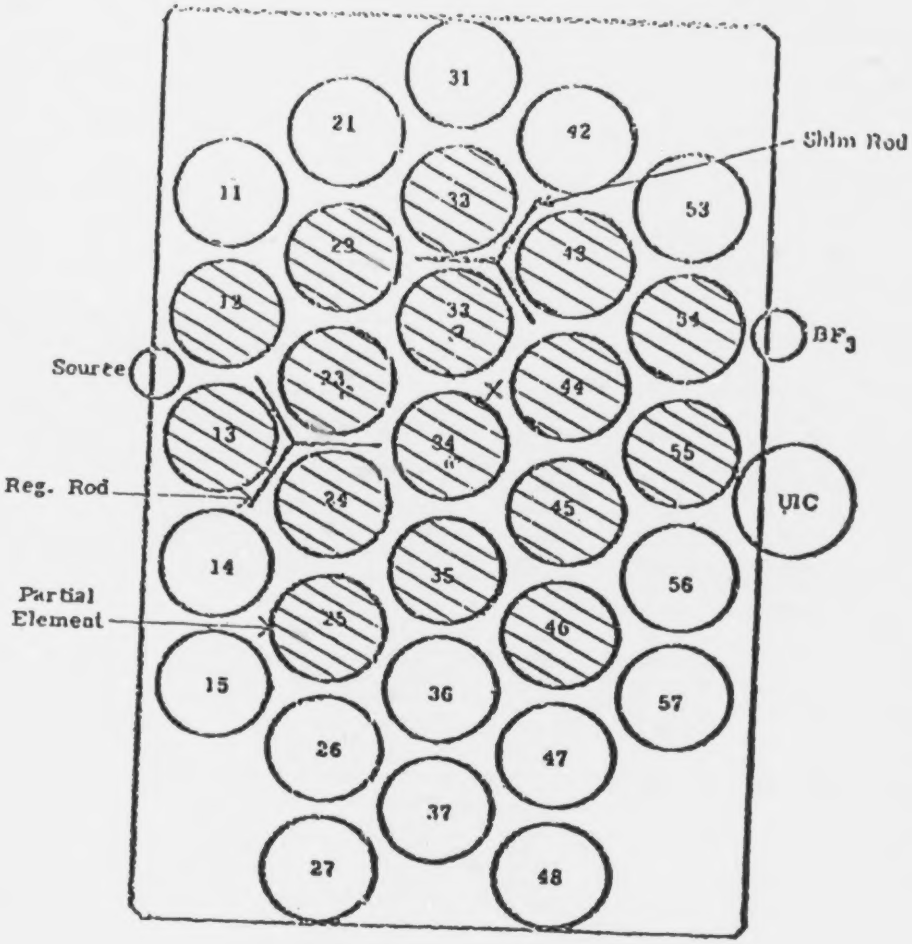
The reactor vessel consists of a large aluminum drum eight feet high and ten feet in diameter. The reactor core is centrally located at the bottom of the vessel and consists of a grid plate and stand upon which the fuel elements are mounted.

There are fifteen full fuel elements and one partial fuel element. The full fuel elements contain a nominal 200 grams of enriched uranium and the partial fuel element contains a nominal 24 grams of enriched uranium. Each fuel element has six concentric cylinders and each cylinder is divided into three sectors of 120 degrees each. The plates comprising these cylinders are fabricated in the form of a sandwich. The meat of the sandwich is made of an alloy of uranium and aluminum and is clad on both sides with aluminum. The mounting array of the fuel elements is shown in the accompanying diagram.

On March 24, 1964 the MCZPR became the first critical reactor in New York City. It is still the only critical reactor of any kind in New York City.

GRID POSITION NUMBERING

MANHATTAN COLLEGE ZERO POWER REACTOR


31
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42
Shim Rod
11
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BF3
Source
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55
Reg. Rod
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Partial Element
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48

Core Loading Indicated
by Diagonal Shading

Radiation Center Oregon State University Corvallis, Oregon 97331 (503) 754-2341

November 18, 1983

Dr. D. G. Harris, Chairman
LEU Study Group
Dept. of Nuclear Engineering and Science
Rensselaer Polytechnic Inst.
Troy, NY 12181

Dear Dr. Harris:

Thank you for your letter describing the NRC sponsored study being conducted to establish the major impacts of converting research reactors from high enriched uranium (HEU) fuel to fuel containing lower enriched uranium (LEU). The study questions posed are very comprehensive, and we will attempt to provide as much information as possible. However, in the interest of meeting your time requirements we will direct our responses to the points which are of greatest concern to us and for which we have readily available information.

As you may already know, we have previously participated in the earlier study of this matter conducted by the Test, Research, and Training Reactor (TRTR) organization, and have recently sent letters to Commissioners Gilinsky and Palladino expressing the difficulties we have with such a program. From this you can no doubt see that we are both interested and concerned about the prospects of having to convert our reactor from HEU to LEU fuel, and do not wish to do so for reasons we will detail below.

1. The possibility of a complete refueling of the Oregon State University TRIGA Reactor (OSTR) introduces a number of very significant concerns on our part, including the obvious ones of cost, operational considerations and licensing. We need not dwell upon the fact that the University's budget could not support such a major undertaking, and in light of our current budget forecasts, we do not feel encouraged by the prospects of being required to undergo a conversion to lower enriched uranium fuel until our current fuel is expended.

2. The OSTR currently possesses enough FLIP fuel in the core to operate for about 80 years, which is well beyond the projected life of the reactor. Exchange of this fuel for new LEU TRIGA fuel would, as you mentioned, involve many costs, including an estimated \$520,000 for new fuel alone, \$60,000-\$70,000 for shipping spent fuel, and other costs for SAR preparation, review, etc. In addition to these costs, we are concerned about facility crane capacity and the need to upgrade our existing crane, which would be a further additional expense. With respect to this

matter, most of the shipping casks projected as usable for spent fuel shipments from research reactors weigh about 13 tons. The crane capacity in our facility, and we suspect in many other university reactors, cannot handle this weight. One university reactor recently indicated that it cost them approximately $25,000 to upgrade their crane to handle 15 tons. This is certainly not an insignificant additional cost and represents a time consuming engineering effort.

3. Oregon State University has worked very hard to develop the first fully verified self-protection program for TRIGA fuel. With this program in place and operational, our fuel is now kept well above the 100 rem per hour at 3 feet threshold. Should we be requested to refuel, we will need to handle fuel which has intentionally been made much more radioactive (>100 times more radioactive), rather than handling fuel which has been allowed to cool in the traditional manner. This will obviously reduce our ability to meet our commitment to the Commission to keep radiation exposures to personnel as low as reasonable achievable. Should the fuel be allowed to cool, we will then lose the self-protecting radiation level deterrent which is necessary from a physical security standpoint. From our viewpoint, the wisest path to follow is to avoid the unnecessary occupational radiation exposures from handling highly radioactive fuel, and avoid the need for added physical security measures to compensate for non-self-protecting fuel by continuing to use the OSTR fuel as it now exists safely in the core.

4. Use of LEU fuel in the OSTR will probably not have major effects on our neutron fluxes at steady state powers, but most agree that the pulsing characteristics will suffer to some extent. With respect to this, we have two major concerns regarding the acceptability (to us and to the NRC) of the new LEU fuel manufactured by G. A. Technologies. First of all, the new fuel has been tested by the DOE only in long steady state runs to ascertain performance, burnup, etc. They have performed no testing from the pulsing standpoint, and none is planned. GA has pulsed the fuel to some extent, but we have no idea if the NRC will accept their results and do not know what the NRC will require in terms of license limitations on pulsing, which is a very important consideration to us in our operations. Additionally, the numerical values used to describe expected fission product releases in the event of fuel cladding failure (the fission product release fractions) have been carefully reviewed and accepted by the NRC for our current fuel. Since these values weigh heavily on the results of any projected accident scenario involving fuel cladding failure, they are of great importance in preparation of the facility Safety Analysis Report and Emergency Response Plan. At this time we are concerned about what these new values might be, if they have been deemed acceptable by the Commission, and how they will effect our existing accident projections and emergency response requirements.

As a result of these factors, we feel that although GA Technologies may be in a position to manufacture LEU fuel for TRIGAs in adequate supply, there are a number of unknowns associated exclusively with installation, use and licensing of such fuel for which we must have answers before the university TRIGAs are asked to accept the fuel for use in their reactors.

5. We are not convinced that TRIGA FLIP fuel is a prime target for theft or diversion of special nuclear material (SNM), and do not believe that its replacement based on security benefits is justified. In particular, TRIGA FLIP fuel is only about 70% enriched and has the ^{235}U contained in a fuel matrix consisting of uranium-zirconium-hydride with an erbium burnable poison. While perhaps it is not impossible to reprocess this type of fuel for uranium recovery, the fuel material is much more difficult to deal with chemically than other fuels commonly used by nonpower reactors, and, as a result, is quite likely the least desirable of all fuels for SNM theft and diversion. Additionally, the shipment of FLIP fuel from TRIGA research reactors under the proposed conversion program will create security considerations demanding much more attention than would be required if the fuel were simply left irradiated to self-protecting levels in the respective reactor cores.

6. Another aspect of this matter which we feel needs to be studied is the degree, if any, to which the HEU to LEU conversion effort will apply to all United States research reactors, and not just to those at universities. At the present time, we understand that U. S. Department of Energy reactors will not be asked to consider such conversions.

In closing, let me again state that we recognize that all of your questions were not fully addressed. We do, however, sincerely hope that the information submitted will be of help in convincing the NRC that an across the board conversion of all research reactors to LEU is not a wise, or perhaps even possible, move now or in the future. We also thank you for inviting us to participate in this study. I hope this letter reaches you within the time frame required, and we will be happy to answer any questions you may have after reviewing our report.

Yours sincerely,

C. H. Wang
Reactor Administrator
Director, Radiation Center

CHW/jrl
cc: Director, Oregon Department of Energy
A. G. Johnson, Assistant Director, Radiation Center
S. E. Binney, Chairman, Reactor Operations Committee
B. Dodd, Assistant Reactor Administrator
T. V. Anderson, Reactor Supervisor

TEXAS ENGINEERING EXPERIMENT STATION
THE TEXAS A&M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS 77843

NUCLEAR SCIENCE CENTER
409/845-7551

31 October 1983

Dr. Thomas Parkinson, Chairman
VPI Nuclear Engineering Department
Nuclear Reactor Lab
Virginia Polytechnic Institute
Blacksburg, Virginia 24061

Dear Tom:

I am writing in response to your call for information concerning the conversion of our reactor (NSCR) to LEU fuel. In general I approve of a long range plan to convert research and test reactors to LEU, but I have many concerns of immediate conversion. In the case of our reactor which is presently fueled with 70% enriched FLIP TRIGA fuel, I have no immediate desire to convert to LEU. Conversion would be of interest only if we were in a reactor power upgrade program involving the use of the newly developed TRIGA LEU fuel designed for forced cooling. G.A. has operated with some of the new 20/20 fuel in their reactor, and testing of this fuel in steady state burnout has been completed by Argonne National Lab. Jim Snelgrove reported on this at the TRTR meeting. I have been in contact with Jim on the general test program of LEU TRIGA fuel and he agrees with me that a complete test would involve pulsing of the fuel after burnup. Due to the physical shape of the test fuel, G.A. indicates that they cannot pulse the fuel that has been tested by Argonne. The steady state test did produce good results. The following are my statements concerning LEU conversion of our reactor:

1. The cost to replace our present HEU fuel would be $750,000 for fuel alone. This cost must be handled outside the University. DOE is the agency most likely to supply these funds.

2. The cost to prepare licensing material would have to be borne by someone other than the University.

3. The funding to ship present HEU fuel for deposition would have to come from outside the University.

4. Licensing by the NRC would have to be done in a timely manner and open hearings involving the general public must be avoided.

5. Staff time expense and material cost to install and test the new LEU fuel in a new core configuration should be supported outside the University.

6. No research, test or training reactor should be forced into a LEU conversion.

7. LEU conversion must be technically feasible.

8. There should be documented verification of the performance of LEU fuel prior to undertaking such a heavy cost oriented and time consuming program.

I hope this information and comments will be helpful to you in your study. I apologize for the delay in responding to the letter sent out by Donald R. Harris but I wanted to weigh and consider the TRTR meeting comments and discussions in establishing my position on LEU.

Sincerely,

D. E. Feltz

Donald E. Feltz
Director

DEF/ym

cc: Dr. Carl Erdman, Head, Department of
Nuclear Engineering and Head,
Nuclear Engineering Research, TEES

University of Wisconsin

NUCLEAR REACTOR LABORATORY
NUCLEAR ENGINEERING DEPARTMENT
PHONE 262-3392, AREA CODE 608

ADDRESS:
130 MECHANICAL ENGINEERING BUILDING
MADISON, WISCONSIN 53706

September 1, 1983

Dr. D. R. Harris
NES Building
Tibbets Avenue
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Sir:

The following information is furnished in response to your letter dated August 29, 1983. The responses refer to the University of Wisconsin Research Reactor, USNRC Docket #50-156, license R-74. Items are numbered to correspond to the request for information in your letter.

1. Functional Impacts

a. Estimated cost of conversion to LEU fuel would be primarily fabrication and shipping cost of the replacement fuel plus shipping our HEU fuel back to DOE channels. New fuel fabrication and shipping cost is estimated at $300,000. I have no idea what costs are involved in shipping the present HEU fuel. In any event, conversion back to LEU fuel will involve a lengthy process as we would have to switch over in such a manner that we would not have more than 5 kg of HEU fuel on hand that is not self-protecting. We believe this would require a three-step changeover. We would not expect any loss of revenue during the stepwise changeover since we would have to continue approximately the same amount of full power operation.

The cost of SAR preparation and defense would be dependent upon the fuel choice for replacement. We are currently licensed to operate with "standard" TRIGA fuel, TRIGA FLIP fuel, or a mixture of the two. If we reverted to the original fuel type, there would be no cost. If we used erbium-loaded LEU fuel, the cost is estimated at $5,000.

We foresee no benefits from the conversion as our security plan is based on Category II material.

b. We could revert to the original fuel type with no reduction in capability except for severely limited fuel lifetime. Since we currently do some full power operation just for maintaining the fuel at self-protecting levels, it is possible that we would reduce our full power operating time to the bare minimum to carry out our teaching and research work load.

c. We expect no profound changes.

d. If federal funding were available to cover full cost of conversion we would convert. If state funds would be required, it is likely that decommissioning of the facility would result. We have no estimates of the cost of decommissioning, but I expect it would be in the range of $300,000.

e. I believe the net cost would be $350,000 or more. I see no benefit, nor any great detriment to our program, however.

2. Licensing

a. None.

b. Variable depending upon fuel type selected. None for reverting to "standard" TRIGA fuel.

c. Same as b.

d. Same as b.

e. Probably.

3. Feasibility

a. No.

b. No.

4. Scheduling

a. Unirradiated -- 2075 grams U^{235}
Irradiated -- 11093 grams U^{235}.

b. Yes.

c. Conversion from "standard" TRIGA fuel to FLIP fuel:

9 FLIP bundles installed - March 1974
6 additional bundles installed - January 1978
21 FLIP bundles installed - June 1979
Full FLIP core (23 bundles
in present operational core) - August 1979.

Conversion back to "standard" fuel: A basic assumption made here is that each batch of HEU fuel can be shipped offsite 180 days after the fuel is removed from the core.

Ship all unirradiated FLIP fuel -- starting time 0 --
Reduce core to 15 FLIP bundles as soon as unirradiated fuel is shipped offsite.
Six months later -- ship 8 irradiated bundles, remove 6 additional bundles (cannot operate without at least 9 FLIP bundles in the core).
Twelve months later ship 6 FLIP bundles, remove last FLIP fuel from core.
Eighteen months later ship last of FLIP fuel.

d. We would schedule each core change for the summer months when our teaching load is lightest. I expect that one-year time steps are more realistic than the six-month intervals I indicated above.

e. Negligible if we go back to "standard" fuel.

f. One year.

g. None.

h. One month per core modification.

i. Our on hand FLIP fuel will last the lifetime of the facility. Our license expires at the end of 1999.

j. Six months.

A final comment: Going back to LEU fuel would not seriously degrade our operation -- after all, that is where we started from. It would bring back the original problem that was the motivation for going to HEU fuel, which is securing fuel cycle support to maintain core reactivity at reasonable levels.

Very truly yours,

R. J. Cashwell
Reactor Director

RJC:mld

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Washington State University/538/

1. Functional Impacts

a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

$250,000

b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

Expect major effects on neutron spectrum and flux.

c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

Major impact on NAA research programs.

d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Please consider costs of decommissioning if applicable.

Would expect full cost reimbursement for conversion.

e. What would be the net cost/benefit of conversion of your reactor to LEU?

Large cost and negative benefits.

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Washington State University /538/

2. Licensing

a. Safety-related technical problems, if any.

Possible sacrifice of prompt negative temperature coefficient.

b. Man-month requirements for SAR preparation and defense.

12 Man-months $\pm^{12}_{0}$

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

No licensed shipping cask available.

d. Problems related to additional hearings and other processes, if any.

Must avoid public hearings

e. Would a NUREG licensing guide be useful to you?

YES

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Washington State University /538/

3. Feasibility

The NRC "Statement of Policy", August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs". Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

NO

b. Based on use of advanced fuels once these are demonstrated and available?

YES

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Washington State University /538/

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?

"Not for publication". Authorized to possess 15 kgm > 20% Enrichment

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?

Yes; 10-15 years

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.

~ 5 years HEU
~ 2 years LEU

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?

After funding is provided

e. Calendar time to prepare SAR and license modifications.

2 years

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.

Should be provided by GA

g. Calendar time to plan and effect engineering changes, if any.

NONE

h. Calendar time to carry out additional LEU-related start tests.

6 months

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.

10-15 years

j. How long afterward could you ship your last HEU fuel?

2 years

UNIVERSITY OF CALIFORNIA, LOS ANGELES UCLA

BERKELEY · DAVIS · IRVINE · LOS ANGELES · RIVERSIDE · SAN DIEGO · SAN FRANCISCO SANTA BARBARA · SANTA CRUZ

2567 Boelter Hall
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
LOS ANGELES, CALIFORNIA 90024

September 7, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Department of Nuclear Engineering
RENSSELAER POLYTECHNIC INSTITUTE
Troy, NY 12181

Dear Dr. Harris:

Your questions are interesting and raised some considerations which had not previously occurred to me. I'll summarize the points of principle concern to UCLA.

1. The cost to UCLA of the four year struggle to renew the (contested) operating license is probably on the order of $250,000. The end is not yet in sight. I do not think that UCLA will pay another quarter of a million dollars for a new core. Government funding will be essential.

2. There is insufficient technical information describing the hypothetical LEU fuel for an Argonaut reactor. If the fuel plates are of the same dimensions as the present plates, and the water channel remains the same, then the neutronic properties can be estimated. Metallurgical properties (clad meat bond with a meat containing 60% U) seem uncertain. If the geometry changes, then everything becomes uncertain.

3. Start-up testing requirements are uncertain and hinge upon the same technical uncertainties expressed in item 2 above. If extensive, it could have a substantially dampening effect upon the desirability of continuation. The time scale I cite of 3 to 4 years is that over which significant data were collected by students following the 1960 start-up. It is unlikely that we can generate a comparable environment and enthusiasm today.

4. My response to 1.A Benefits is partially conditioned by Intervenor allegations that terrorists can blow up the UCLA reactor and create a radioactive fall-out over the UCLA Olympic Village in 1984. It's not a plausible result, but LEU does nothing to dissuade the attempt.

5. Refueling and spent fuel shipments are both awkward at UCLA. Fuel bundles are withdrawn upward after removing 60 inches of concrete. Unlike a pool reactor, there is then very little shielding between the exposed core and the working personnel. A shipping cask cannot be brought into close proximity to the reactor, hot fuel must be transported about 100 feet across an

open normally public area. Here one is balancing ALARA goals against some vaguer goal of uncertain merit.

To conclude: Government funding is essential. Metallurgical problems are uncertain, nulcear characteristics will be satisfactory if the fuel plate dimensions remain the same. LEU does not remove the principle sabbotage scenario. Refueling and fuel shipments are potentially hazardous operations and require strong justification. In these circumstances, UCLA cannot commit to LEU conversion.

Sincerely,

Neill C. Ostrander

Neill C. Ostrander, Manager
Nuclear Energy Laboratory

NCO/lm

DETAILED RESPONSE

1. FUNCTIONAL IMPACTS

   a. Cost. UCLA has a Fuel Cycle Assistance contract with the DOE. Fuel has been provided by the DOE and the cost of returns is billed to the DOE. The cost of a new fuel loading ($250,000) could not be borne by UCLA. Costs of engineering revisions and SAR preparation/defense are unknown absent specific fuel plate geometry and physical properties. Fuel on hand (in core plus 40% of a fresh core) will probably suffice to the year 2000. Fuel cycle impact would be that of the change-over and one additional spent fuel shipment. Loss of revenue is not a major factor. However, experience has shown that a three to six month turn around is discouraging to clients and school officials.

   b. Benefits. None except the alleged reduction in sabbotage potential. Even that vanishes in the most common scenario--blowing up the reactor.

   c. Effect upon Reactor Characteristics. Unknown.

   d. Effect of Changed Performance upon Programs. Unknown.

   e. Organizational Response to LEU Conversion. Without very substantial government support, decommissioning is the only alternative. A 1980 estimate of decommissioning cost (five year schedule) was about $650,000.

   f. Cost/Benefit of LEU Conversion. Cost is large, benefit small if any.

2. LICENSING

   a. Safety Related Technical Problems. There is no fuel specific information upon which to base a response to this question.

   b. SAR Preparation/Defense. See 2.a above.

   c. Fuel Cycle, Plutonium. Minor, but P_u production estimates must be refined beyond the current UCLA practice of using only an upper bound estimate.

   d. Hearings. As the present UCLA burden is enormous, the pressure to convert has already been applied, the incremental effect does not appear to be very great.

   e. NUREG Usefulness. A NUREG generically oriented toward Argonaut reactors could be helpful if it provided technical information. Guidance on start-up testing requirements would be useful.

3. FEASIBILITY

Information available to UCLA is insufficient for response to this question (geometry, physical properties).

4. SCHEDULING

a. Present Inventory of HEU, U-235 Isotope. Approximately 1370 gms unirradiated, 3550 irradiated.

b. Life of Existing Core. Most of the core will probably last the lifetime of the reactor.

c. Refueling Schedules. No readily predictable impact except for the one-time change over.

d. Scheduling of the Transition to LEU. The probable sequence, assuming no significant core modification is: 1) shut down for cool-off upon receipt of LEU core loading, 2) return unirradiated HEU to the DOE, 3) enter core, transfer irradiated fuel to dry storage, 4) load new fuel. The sequence could possibly be accomplished in one month. The irradiated fuel would probably be held for several years prior to removal from the site.

e. Time to Prepare SAR and Amend License. Unknown. Insufficient technical description of fuel.

f. Preparation of Fuel Specs, Drawings, Fuel Acquisition. Some of this should be done generically, but the greatest delay might be in securing government funding. The last fuel acquisition was fabricated in the Los Angeles area, communications were very easy. Approximately a year elapsed between contract and delivery dates.

g. Engineering Changes. Changes are undefined.

h. Start-up Tests. A complete reassessment of all reactor parameters could extend over 3 or 4 years. During that interval, core access requirements would limit operation to low power. In many respects, the UCLA reactor would be out of business for that period.

i. Time to Burn-up Available HEU. Assuming that 3500 gms of U-235 suffices to make the reactor critical, the excess on hand, 1420 gms consumed at one gram per year would last 1420 years. If burn-up is arbitrarily limited to 10%, the estimate falls to about 400 years. Burn-up is not a core-life determining factor at UCLA.

j. HEU Cool-off Period. Two to five years. UCLA has only one such experience. There was no early pressure to ship and the holding period was at least six years. Personnel exposures were minimal in this experience.

COLLEGE
OF
ENGINEERING

NUCLEAR FACILITIES DIVISION
UNIVERSITY OF FLORIDA
DEPARTMENT OF NUCLEAR ENGINEERING SCIENCES
102 NUCLEAR REACTOR BUILDING
GAINESVILLE, FLORIDA 32611
AREA CODE 904 PHONE 392-1429

September 29, 1983

Dr. Donald R. Harris
Chairman, LEU Study Group
Department of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, New York 12181

Dear Dr. Harris:

This letter is intended to supply some of the information that you requested in your letter of August 29, 1983. Although many of the items for which you requested responses are not specifically addressed, we feel that the contents of this letter will delineate the unique position of the University of Florida Training Reactor with respect to the LEU conversion effort. Basically, we have no problems with the LEU conversion because of special circumstances.

Fortunately for the University of Florida LEU conversion effort, we have a large quantity of ~4.8% enriched, UO$_2$-filled SPERT fuel pins which will fit into the UFTR core with essentially no requirements for changes although the pins in place of plates will require new grids. We have essentially completed neutronic, thermal-hydraulic and shielding calculations needed for this conversion These involved at least a man-year or more effort. We estimate the conversion itself will cost $50,000-$60,000 with the SPERT fuel used as-is. This cost we hope to have covered by the Department of Energy using the UFTR as a model for later conversions.

We expect a flux increase of ~ a factor of 2 at best (with a flux optimization scheme developed) in the maximum flux level to be attained and no problems in other areas. We expect the conversion itself will require 2-4 months down time and so will need to be carefully timed and preplanned to minimize impact. As for the economic impact, we anticipate a $5,000-$10,000 loss of revenue from the down time in addition to the loss of research and laboratory capabilities for our faculty and students.

The licensing on this conversion, principally the Safety Analysis Report, is anticipated to require about a 3-4 man-month effort and represents a major remaining effort. Therefore, SAR preparation and subsequent defense will probably involve about 4 months.

We currently have about 4.4 Kg of HEU on hand (enough to last 20 years at present rates of consumption). All but about 0.8 Kg is irradiated. Because of our low energy generation (less than 10,000 KW-hr in an average year), we have little concern with scheduling fuel manufacture and delivery. With the fule currently on hand and with anticipated increased UFTR utilization, we would still not need new fuel before the late 1990's.

Although we have not answered all your questions, we hope that the information contained in this letter will be of assistance. If you have further questions, please let us know.

Sincerely,

William G. Vernetson

William G. Vernetson
Reactor Manager

WGV:bg
cc: N.J. Diaz

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

College of Engineering
Department of Nuclear Engineering

September 12, 1983

Dr. Donald R. Harris
Chairman
LEU Study Group
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Dr. Harris,

Due to the short time between receipt of your letter of August 29, 1983 and the requested response date of September 9, 1983, most of the asked for items of information cannot be provided.

The University of Washington and the State of Washington have been subjected to severe financial exigencies during the last few biennia and the picture is not expected to be significantly improved for some time. Thus, even if the DOE provided full funding for just the expenses associated with fabricating and delivering LEU fuel, the costs of redesign, relicensing and any necessary modification of our reactor would be beyond our means.

Therefore, if the NRC mandates that the UWNR be converted to LEU fuel, we would have no alternative but to shut down. On the other hand, we have essentially a lifteime HEU core. Thus, if lifetime-core research reactors were exempt from the LEU requirement, we would be able to continue. Similarly, if DOE were to make sufficient funds available to underwrite the real total costs of conversion to LEU we would remain in operation.

Loss of the UWNR would have a profound detrimental effect on the academic and research program of our Nuclear Engineering Department.

With respect to your explicit questions, the only information immediately on hand is our inventory which is made up of a total of 4598.1 g of HEU (fully enriched) of which 3677.9 g are in the core and the balance (933.5 g) are in storage at the reactor. The stored HEU is composed of 224.4 g of irradiated fuel in the form of 2 partial (8 plate) bundles and 698.1 g of unirradiated fuel in the form of 2 full unirradiated bundles, plates, fuel samples, and scrap.

Answers to the remaining questions would require substantial time and effort. As the staff at our reactor facility is limited, we will not be able to respond for some time. It would be beneficial to know the level of urgency of obtaining the answers to the remaining questions so that we can schedule staff effort.

We would be grateful to be kept informed of developments in this issue and will be happy to contribute what we can.

Sincerely,

Maurice A Robkin

Maurice A. Robkin
Professor and Director
Nuclear Reactor Laboratories

MAR:lk

COLLEGE OF ENGINEERING

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Blacksburg, Virginia 24061

NUCLEAR REACTOR LABORATORY

September 7, 1983

Dr. Donald R. Harris
Department of Nuclear Engineering
RPI
Troy, NY 12181

Dear Dr. Harris:

I am writing in response to your letter of August 29 regarding conversion of the Virginia Tech Argonaut Reactor (VTAR) from high to low enrichment uranium (LEU) fuel.

1. Introduction

The VTAR is currently licensed to operate at a maximum power of 100kw using HEU-MTR type fuel. The U-235 loading in our fuel is approximately 0.6 gm cm^{-3} and the original Argonaut was designed to operate with LEU fuel. Accordingly, we anticipate no major technical problems in converting to LEU fuel. We are very concerned, however, with the financial impact of conversion and we suggest that a cost-benefit analysis would be appropriate and useful. In short, if the NRC mandated that we convert to LEU fuel and if no financial support were made available from DOE, we would have no alternative but to shut down our reactor facility. Since we are heavily involved in the training of engineers and nuclear scientists, we feel that cessation of our reactor operation would have a substantial long-term impact on the availability of competent engineers and scientists for the nuclear power industry.

2. Functional Impacts

a. Costs

(i) Fabrication of replacement LEU core; 12 elements containing 12 plates each + 20 spare plates; ... 164 plates @ $500 per plate $82,000

(ii) Shipment of existing HEU core; 12 elements @ $20,000 per element $240,000

(iii) Engineering modifications $0

(iv) SAR preparation: 6 man months @ $2,000/man month . . . $12,000

(v) Revised functional optimization 0.0

(vi) Loss of revenue during conversion; 4 months down time @ $2,500/month . . . $10,000.00 TOTAL: $344,000.00

2. Functional Impacts (continued)

   b. Benefits

      I cannot see any financial benefits, other than a decreased vulnerability to unauthorized diversion of HEU fuel.

   c. Effects on Functional Capability of the VTAR

      Minor changes in the thermal flux per unit power and in the neutron spectrum. No significant deterioration in performance.

   d. Effects on Research, Training and Test Programs

      No significant effects

   e. Response of VTAR and the VPI&SU Administration

      As discussed in paragraph 1, if a conversion to LEU were mandated without financial compensation, the VTAR would be shut down. This action would necessitate submission of a decommissioning plan to the NRC. We recently estimated the costs of decommissioning to be about $800,000.

   f. Net Cost/Benefit of Conversion

      Since we cannot evaluate any financial benefit the C/B ratio is infinite! The total costs for conversion are estimated in paragraph 2.a. to be $344,000.00.

3. Licensing

   a. Safety related technical problems

      None anticipated

   b. SAR preparation and defense

      Estimate 6 man-months (para. 2.a. iv.)

   c. Fuel cycle licensing problems

      None anticipated

   d. Problems with additional hearings

      None anticipated; our application for license renewal has been pending with NRC for about 2 years

   e. NUREG licensing guide

      This would be a useful document to aid in SAR preparation.

4. Feasibility

a. LEU replacement

Should be feasible using existing technology. Replacement of HEU plates can be done with identical sized LEU plates. Thus the thermal-hydraulics effects should be minimal. Some small change in the heat transfer characteristics of the LEU plates is not expected to be significant, although we have not done any calculations on this change.

b. Advanced LEU fuel

Should not be required for the U-235 fuel loading we use.

5. Scheduling

a. Present HEU fuel inventory

3.2 kg U-235 in irradiated fuel
2.2 kg U-235 in unirradiated fuel
We plan to transfer our unirradiated fuel within the next 3 months so that we will qualify as a Class III facility.

b. Core lifetime

The existing HEU core is expected to last for another 10 years at least.

c. Refueling schedule

Due to our low operating power (100 kw) we don't expect to add any new fuel for about 5 years.

d. LEU fuel transition

If we are forced to go to LEU fuel, we would anticipate making the change in CY 1986.

e. Time to prepare SAR and license modifications

About 1 year calendar time

f. Time to prepare LEU fuel specifications and procure fuel

About 6 months. We would work with the fuel vendor (B&W?) on this problem.

g. Time for engineering changes

None anticipated. We are currently installing a new secondary cooling system and modifying the primary cooling system.

h. Time to carry out LEU start-up tests

3 months calendar time.

5. Scheduling (continued)

   i. Time required to burn existing HEU fuel

      More than 10 years.

   j. Subsequent time to ship HEU fuel

      Depends on availability of approved transfer cask.

6. Summary

If the primary objective of the NRC is to reduce the vulnerability of research and test reactors to theft of HEU, then we feel that Argonaut reactors like ours should be assigned a low priority for making the transition. We have a very low inventory of HEU and it is essentially all self-protected.

Sincerely,

Peter D. Holian

Peter D. Holian
Reactor Supervisor
Nuclear Reactor Laboratory

PDH/smw
cc: T. F. Parkinson, Director, VTAR
R. A. Teekell, Chairman, Reactor Safety Committee (VTAR)

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Iowa State University

1. Functional Impacts

a. Costs (in dollars if possible) of LEU-conversion-related fuel, fuel shipment, engineering modifications, SAR preparation and defense, revised fuel cycle, revised functional optimization, and loss of revenue during conversion. Same for benefits.

SAR Preparation	- $15,000	NO Benefits
Loss of Service	- 10,000	
LEU Core	- 90,000	
HEU Shipment	- 100,000	

b. Effects on neutron flux level, spectrum, duty factor, and other technical measures of functional capability. Here the various alternatives for advanced fuel development may be appropriate to your response.

Negligible

c. The effects of changed technical performance of your reactor on specific research, training, and test programs. How would these changes affect revenue?

Negligible

d. What would be your organization's response to LEU conversion, assuming various alternatives for government support? If some programs would be curtailed, what would be the impacts of such curtailments? Please consider costs of decommissioning if applicable.

If federal support is not available, reactor will be shutdown. Decommissioning cost ~ $700,000

e. What would be the net cost/benefit of conversion of your reactor to LEU?

NO benefit!

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Iowa State University

2. Licensing

a. Safety-related technical problems, if any.

NONE

b. Man-month requirements for SAR preparation and defense.

6 man months

c. Licensing problems for the fuel cycle, including any related to spent fuel and to plutonium build-up.

NONE

d. Problems related to additional hearings and other processes, if any.

Unknown

e. Would a NUREG licensing guide be useful to you?

Yes

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Iowa State University

3. Feasibility

The NRC "Statement of Policy", August 24, 1982 (FR 37007), the Use of High-Enriched Uranium (HEU) in Research Reactors, gave as the objective of the U.S. Reduced Enrichment Research and Test Reactors (RERTR) program the development of "research and test reactor fuels which will allow the substitution of uranium of low enrichment (LEU, less than 20%) for HEU and which will not significantly affect reactor performance characteristics of fuel cycle costs". Based on this definition of feasibility, are there any aspects of conversion to LEU (e.g., reduced coolant channels, less favorable reactivity coefficients, etc.) that would result in power reduction or other degradation of performance:

a. Based on use of fuels fabricated with existing technology?

Yes

b. Based on use of advanced fuels once these are demonstrated and available?

NA

LOW ENRICHED URANIUM FUEL CONVERSION SURVEY

ORGANIZATION: Iowa State University

4. Scheduling

a. How may grams of unirradiated/irradiated HEU fuel have you on hand?

3 kg Irradiated
1.9 kg Unirradiated

b. Will your core last for the reactor lifetime? If not, when are the next fuel delivery and your next refueling?

YES

c. Please describe approximate refueling schedule with HEU fuel and an anticipated refueling schedule with LEU fuel.

LEU refueling after 6 months notice.

d. Assuming the availability of LEU fuel, how would you schedule the transition to LEU?

Same as above

e. Calendar time to prepare SAR and license modifications.

1.5 years

f. Calendar time to prepare LEU fuel specification and drawings, and to obtain fuel based on your experience.

1.5 years

g. Calendar time to plan and effect engineering changes, if any.

NONE

h. Calendar time to carry out additional LEU-related start tests.

3 months

i. Please estimate the time required to burn the HEU fuel which you have on hand or in process of fabrication.

> 10 years

j. How long afterward could you ship your last HEU fuel?

?

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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DEPARTMENT OF CHEMICAL AND
NUCLEAR ENGINEERING

SANTA BARBARA, CALIFORNIA 93106

September 6, 1983

Dr. Donald R. Harris, Chairman
LEU Study Group
Dept. of Nuclear Engineering
Rensselaer Polytechnic Institute
Troy, NY 12181

Dear Don:

This is in reply to your query regarding the impact of the proposed conversion of training and research reactors to low-enrichment uranium (LEU).

We have a low power, low duty cycle training reactor (10 watt Atomics International Model L-77) which we use almost entirely for educating nuclear engineers in a laboratory course. It uses liquid fuel (uranyl sulfate in water), with an enrichment of 90%, and our operating mass is 1225 grams ^{235}U. There is another 10 grams or so of ^{235}U in solution on reserve in case we have to add fuel to maintain reactivity. The fuel should last for the rest of the licensed life of the reactor (to 1995) or until the reactor is decommissioned. Conversion to LEU would thus require unloading and reloading fuel solution which would otherwise not be required.

Some L-77 reactors have been operated with 20% enriched fuel solution, in the same size core vessel. According to Atomics International, the critical mass of 20% enriched fuel is 1400 g ^{235}U and an operating loading may be 1408 g ^{235}U, although the latter has to be adjusted considering the experimental reactivity and license conditions. The critical mass with our HEU fuel is 1213 g ^{235}U. We do not have any provision in our budget for procuring new fuel or shipping old fuel. As a minimum we would have to request the NRC to pay for the costs of appropriate shipping containers, transportation, and disposal of the old fuel, and for the shipping containers, transportation, and cost of the new fuel. Stringent requirements must be placed on the purity of the new fuel, especially chloride concentration, to avoid corrosion of the stainless steel core vessel. Excessive neutron absorbing impurities must also be avoided. We would guess this would amount to tens of thousands of dollars, with waiver of the use charge for the uranium, as is now done for our fuel.

Inasmuch as other L-77 reactors have been licensed with 20% enriched uranium fuel solution, we expect that relicensing would not be a major problem, unless antinuclear activists use this as in excuse to try to shut down the UCSB reactor. Safety criteria should not be affected appreciably. However, we will have to take the time and expense to prepare a modified SAR or at least a license amendment, which might involve several thousand dollars. Draining the old fuel into criticality-safe containers, storage, qualification of shipping containers, reloading new fuel, etc. would all have to be addressed. Some outside consulting help may be necessary for the shipping container design and qualification. The reactor is used in the lab course from April through June, and we would not want to drain fuel until after a period for radioactive decay, so the reactor would have to be drained and reloaded in the fall or winter.

The reduction in flux level and other technical effects on performance because or reduced enrichment are not thought to be serious considering the purpose of our reactor.

We have already installed the security equipment appropriate to the SNM in the reactor and the small amount of reserve solution, thus we anticipate no savings there. The conversion to LEU repesents only a considerable amount of time, labor, and expense to us without a direct benefit that we can see. If government support is not forthcoming to pay for the costs of the conversion, it is quite possible that our administration may decide to decommission the reactor now rather than at end of licensed life (there are researchers already clamoring for the space). We very much prefer to operate the UCSB L-77 reactor as is until 1995.

Sincerely,

Ed Profio

A. Edward Profio
Professor of Nuclear Engineering
Reactor Director

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NUREG/CR-2492
LA-9213-MS

Special Nuclear Material Self-Protection Criteria Investigation

Phases I and II

Manuscript Completed: December 1980
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Prepared by
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Prepared for
Division of Safeguards
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN A7145

SPECIAL NUCLEAR MATERIAL
SELF-PROTECTION CRITERIA INVESTIGATION
Phases I and II

I. INTRODUCTION AND TASK SUMMARY

A. Introduction

The Special Nuclear Material (SNM) that is possessed by nonpower reactor (NPR) licensees is exempt from most 10 CFR Part 73 physical security requirements if the material "is not readily separable from other radioactive material" and "has a total external radiation dose rate in excess of 100 rem/h at a distance of 3 ft from any accessible surface without intervening shielding."[1] NPR licensees have sought to take advantage of the exemption to the rules provided by the radiation level requirement. However, the power levels of many of these reactors are not sufficiently high to irradiate the SNM to a point at which it has a dose rate level of 100 rem/h at 3 ft. Consequently, these licensees have proposed that the Nuclear Regulatory Commission (NRC) either lower the radiation level or use an alternative criterion.

As initially envisioned by the NRC, the 100-rem/h level was to provide a deterrence against theft. The current character of the potential adversary (determined and violent persons with equipment appropriate to their task) has caused the NRC Commissioners to request that their operational staff reassess the appropriateness of the existing criterion.

This report covers Phase I and Phase II of a Los Alamos Scientific Laboratory (LASL) project in which we examined the technical aspects of this criterion and provided technical analyses to support NRC staff policy assessments.

Phase I consisted of six tasks that were needed to provide a data base for Phase II of the study. In Phase I, existing information was collected and, when necessary, analyzed. Discussions and conclusions are given for each task in the same order as they appeared in the LASL proposal.

Phase II included recommended courses of actions, justifications for these actions, and the effect of these actions on several types of facilities. The recommended alternatives, in order of preference, are summarized in Sec. II.

B. Summary of Tasks

Task 1. Analysis of the Equipment, Expertise, and Time Required to Remove Fuel From the Core of All Types of NPRs

At an NPR facility, fuel will normally be in one or more of three locations: (1) unirradiated fuel in a vault-type room, (2) irradiated fuel in the core, and (3) irradiated fuel in a fuel storage pool. Here we are concerned only with the self-protection formed by irradiated fuel, and thus only fuel located in the core and in fuel storage areas will be examined. In some cases, all three locations are in the reactor pool.

There are two general types of NPRs: (1) reactors with the fuel completely enclosed in a tank and/or solid shielding, and (2) reactors with the fuel accessible from above the core, such as a pool reactor. The enclosed reactors usually have massive blocks of shielding that must be removed for access to the core. The top plate of a tank-type reactor or a large shielding plug must also be removed (a very difficult task). Once either is removed, removing fuel is similar to removing fuel from a pool-type reactor. Normally a crane is required for removing the shielding plug or tank top. This removal takes time under normal and theft conditions. In addition, as an extra measure of security, the crane can be locked in place and provided with on-off alarms and so on. Thus the time to obtain access depends on the reactor design and is site specific. The discussion that follows is concerned with removing fuel from a pool-type reactor and gives conservative, low fuel-removal times and doses.

The minimum equipment needed to remove irradiated fuel from an open pool are a fuel-handling tool, a truck, and radiation shielding. The fuel-handling tool could be one normally used for moving the fuel. If one is not available, the fuel-handling tool could be as simple as a hook on the end of a rope. Most fuel elements have grappling pins or holes that would be easy to grasp with a hook and then the elements can be lifted to the pool surface. At the pool surface, the elements could be shackled by hand or, to reduce the radiation dose, by a stick or rod.

A truck or other vehicle would be needed to transport the fuel from the reactor site. The volume and weight of the fuel would not be a critical factor in determining the vehicle size. Twenty-five to thirty plate-type fuel subassemblies containing 5 kg of uranium weigh less than 50 kg and can be stacked in a volume approximately 0.6 by 0.6 by 1.0 m. TRIGA fuel is about three times as dense, but can be stored in about the same volume. However, if these stacks were immersed in water and not disrupted, in most scenarios they would constitute a critical assembly.

The size of the truck would be determined primarily by the amount of shielding that the adversary group decides is necessary. The shielding could be designed to either minimize personnel dose or to minimize the possibility of detection as the truck is driven from the reactor site. The first criterion is arbitrary. The second is the more stringent, and the shielding required is determined by the detection limits of survey teams, which vary depending on the type of search equipment employed.

If the search team used a fixed-wing aircraft, a large area could be covered in a relatively short period of time. A search aircraft flying 300 m above the ground at 220 km/h with a 300-m grid spacing could cover approximately 70 km^2 in 1 h. An irradiated fuel element having an air dose reading of 560 mR/h at 1 m (unshielded) would almost certainly be detected.

The speed and area coverage of the survey are reduced considerably if a helicopter is used, but the detection limit is improved. A search helicopter flying 60 m above the ground at 130 km/h at with a 75-m grid spacing could cover approximately 10 km^2 in 1 h, a reduction by a factor of 7 in area covered compared to the fixed-wing aircraft. However, the detection limit is improved by a factor of 60 or 9 mR/h at 1 m.

If the search team used a van, the detection limit is similar to that of the helicopter. For hand-held instruments, the limit is improved over the helicopter by approximately a factor of 60.

A lead blanket could be prepared to lay over the fuel-element assembly while it is being moved from the pool to the truck. The lead shield would have to be approximately 30 mm thick to reduce the radiation dose by a factor of 10. A blanket large enough to cover three sides of a fuel element assembly weighs about 45 kg. This would be unwieldy and probably would not be practical as it would increase the residence time around each assembly. The adversary would desire to simply move the fuel element assembly as quickly as possible.

Two other types of local shielding might also be considered: lead aprons and shielded transfer casks. Lead aprons, such as used in x-ray facilities, are not practical. They are essentially useless for fission-product gamma ray energies because they give a dose reduction factor of less than 10. Most research reactors have shielded transfer casks for moving irradiated elements. These casks are very heavy (typically several thousand kilograms) and must be moved with a crane. This can be made difficult by locking the crane out, fixing the crane with an alarm, or otherwise securing it. Further, the use of a crane and shielded cask would significantly increase the time that a group must remain in the facility, thus increasing the possibility of detection by a security force.

The simplest form of shielding in a vehicle is concrete block. The weight of the block used depends on the dose attenuation required. Attenuation factors and estimated shield weights for 30 elements in a cavity 0.6 by 0.6 by 1.0 m with a shield on each of six faces are listed below.

Attenuation Factor	Shield Weight (kg)
10	910
100	1820
1000	2730
10 000	3640

Attenuation factors of 10 or 100 could be provided in a small moving truck or heavy duty pickup or van. Providing shielding above the fuel would be difficult and would add considerable weight to an already overweight vehicle.

The successful theft of NPR fuel would be much easier with the assistance of a knowledgeable insider. An insider could be aware of the details of the facility security system. Section 73.67 of 10 CFR Part 73 requires that NPRs with inventories of SNM of moderate or low strategic significance store these materials in areas that are monitored with an intrusion alarm or other systems to detect unauthorized entry or activities. The requirements also call for a security organization, periodic surveillance by the security organization, and an appropriate response force. To meet these requirements, most facilities are using intrusion alarms on all doors to fuel storage areas, motion detectors in storage areas, and other similar devices. Only a few authorized individuals have knowledge of the operation of these detectors. Further, most facilities have radiation monitors that will alarm locally if irradiated fuel is moved about in air. The alarm may attract attention and thus deter the adversary group. Only a few authorized individuals can change the set points on these monitors.

Other useful information for a successful theft includes the location of the fuel, fuel loading data, and fuel enrichment. Some knowledge of shielding and dosimetry would be useful if the adversaries wished to minimize human exposure.

Task 2. Estimate of the Range of Doses Likely to be Received by an Adversary in Attempting to Remove Material

Almost one-half of the licensed NPRs have been reviewed relative to specific site parameters to develop a nominal or average facility for calculational purposes. Based on the present rule, an element radiation level of 100 rem/h was chosen for this purpose.

The number of elements in the core varies, depending whether they are plate- or TRIGA-type elements. There are between 8 and 30 plate-type elements in a core (many cores have nearly 30 elements). Cores using TRIGA-type elements have up to 25 elements in four-rod clusters and up to 112 elements in single SNM rods.

Most plate type elements reviewed contained nearly 175 g of ^{235}U, although the range was from 120 g to 775 g. This, coupled with the nearly 30 elements per core, gave us a nominal 5 kg ^{235}U per core or a formula quality of ^{235}U. Therefore 30 elements were chosen, as many reactors contained close to this number and, at 175 g per element, these give a nearly 5-kg core loading.

1. Removal of elements to pool surface. Because elements remain under water as they are being moved to the surface of the pool, the dose received during this phase is assumed to be negligible. Removing 30 elements using either a grappling hook on the end of a line or using a core-loading tool would take an experienced handler at least 2 min per element (or 1 h) to remove the 30 elements. Under normal transfer conditions, experience has shown that the time needed is closer to 7 or 8 min per element if care is taken not to damage it during transfer. Removing the inner elements takes more time because of the physical interference from the control rod guides and

experimental equipment. No extra time has been allowed for removing these more difficult elements.

2. Transfer of elements from pool surface to truck. This phase of the theft will contribute the largest proportion of the dose received by an adversary, mainly because of the vulnerable position of the adversary relative to the element. Shielding would be impractical during the transfer, and therefore the only way for the adversary to reduce the dose he received would be to decrease his time in proximity to the element or increase his distance from the element.

The distances observed between the pool surface and closest approach for the truck ranged from 25 to 100 m, with the majority of the distances around 50 m. We chose a distance of 50 m without considering the above-mentioned obstacles, except for moving the elements with a very long handling tool (discussed later).

Distances are misleading in themselves as many corridors, doors, airlocks, and steps are encountered at these facilities. The time estimate for this phase does not include the time required to break security.

If an element is carried at arm's-length (approximately 2 ft), the whole body dose rate seen is probably closer to 250 rem/h than 100 rem/h. The transit time is minimized, but the radiation level is great. Running the 50 m would require at least 20 s, and the adversary must do this 30 times. Storage would take an additional 10 s, making the total time near 15 min, or 30 s per element. The dose received for this effort would be 62.5 rem,* and the total time for this transfer phase would be nearly 25 min.

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*(20 s + 10 s) x 30 elements x 250 rem/h-elements x h/3600 s = 62.5 rem

If an element is dragged using a rope or other piece of equipment, the dose received by the adversary would be much smaller, but the time to make the transfer would be extended greatly because of the problem of grasping the elements and going through the obstacles discussed earlier. The adversary would still have to get near the elements while storing them. The dose rate he would receive during the transfer would depend on his distance from the element. A maximum for pool reactors would be the length of a handling tool (approximately 6 m). If we take into account scattered radiation, the radiation dose received during transfer would be closer to 8 rem/h. The transit time would depend on the number of obstacles encountered, but probably would be a factor of 10 greater than for the previous scenario, especially if the element is disconnected accidentally in transit and must be reconnected. The person handling the material would receive a dose of approximately 14 rem.* The total time for this transfer phase would be approximately 115 min.

Thus an adversary could decrease his total whole body radiation dose by a factor of 4 by using a dragging tool but would increase the total expended time in the theft by a similar factor. For computational purposes, we will use the first scenerio.

3. Transfer of elements from the reactor to the processing area. This factor is nearly impossible to quantify as it depends on the specific site. For our purposes, we will assume that the adversary is allowing 30 min before running a significant risk of detection. This time will probably restrict his movement to within 15 miles of the reactor.

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* (200 s + 10 s) x 30 elements x 8 rem/h-elements x h/3600 s = 14 rem.

With no shielding and a distance from the elements to the truck cab of 10 ft, the total radiation the adversary received during this phase would be approximately 135 rem.[*] If a ton of shielding is used, this factor would be reduced (as pointed out earlier) by a factor of 10.

4. Total dose during theft. The total dose to the adversary during these various phases would be approximately 80 rem if he chooses to make the theft quickly and uses a pickup truck with a ton of shielding. The total time needed for the theft would be approximately 2 h. If he chooses to be more careful, he could reduce the total dose to 30 rem, but he would increase the theft time to 5.5 h.

We have shown that the greatest contribution to the dose would, under most conditions, come from the transfer of fuel from the pool surface to the truck. There are great differences between sites in the distance and the number of obstacles that would be encountered during theft. To show these differences, we will describe two existing NPR sites.

Site A. The reactor building is made of heavy-gauge steel with a steel roll-up door mounted between the reactor pool and the closest approach of the vehicle (25 m). The vehicle loading dock is ideal for an unimpeded transfer once the door is in a rolled-up position. Fuel can also be removed through three office-type doors and down a small flight of steps. The distance traveled is approximately 60 m.

Site B. The reactor building is part of a large concrete building set into the side of a hill. There are two massive drive-through doors between the bottom of the pool room (beam room) and the outside. The closest approach for a vehicle is three stories below the pool surface. The total distance is approximately 25 m. If the vehicle does not penetrate the building (that is, stays outside of the doors), the total distance is approximately 125 m. The other way to remove fuel is to go through an airlock, down several flights of stairs, and through several office-type doors, a total distance of approximately 200 m.

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[*] 30 elements x 100 rem/h element x 9/100 x 0.5 h = 135 rem.

Several factors could cause a higher total dose. The calculations are based on elements with a uranium loading of about 175 g each. Moving more elements with less loading requires longer exposure times. In addition, the calculations are also based on a dose rate of 100 rem/h for all elements. The elements would likely be more radioactive, some significantly so.

In most reactor cores, the neutron flux is not flat across the core, and thus the individual element radioactivity varies as the core is traversed. The peak-to-edge ratio of element activity could easily reach 5 for a water-reflected core. As an example, consider a core array of 5 elements by 6 elements. Assuming 100 rem/h on the outside elements and an increase of 3 for the adjacent ring and 5 for the inner elements, the total radiation level for all 30 elements is 5800 rem/h, or an average of 193 rem/h for each element. Thus instead of seeing 3000 rem/h from the total 30 elements, the dose rate would really be closer to twice this value because of the cosine flux profile. Some cores are reflected with more efficient materials, some with reflection on all sides, and some with partial reflection. For a full graphite-reflected core, this ratio between peak to edge could be reduced to a few percent--making the individual element activity nearly constant. Thus the total dose to an individual could be increased by a factor of 2 or 3 from this effect alone, or could be increased by only a few percent for well-reflected cores.

If these two factors were added to the site-specific characteristics for increasing the transit time of fuel removal from the core to the vehicle, the total dose could conceivably be increased up to around 1000 rem.

On the other hand, there are factors that could cause a lower total dose. The time needed to transport the elements to the truck may be less than we noted. In some situations, the truck might be close enough so that the transfer could be done in 10 to 15 s. The dose during loading can be reduced by increasing the shielding and by using less care, such as throwing the elements in the truck in a random fashion. The dose during driving can be reduced by using more shadow shielding and moving the fuel to the back of the truck bed, thus placing a greater distance between the fuel and the driver, and by having a shorter driving time. Finally, the dose per person can be further reduced by using more people to transfer the elements.

Thus the doses received by the adversary can range from tens to hundreds of rem. The most likely dose to a careful adversary is approximately 50 to 100 rem based on elements at 100 rem/h at 3 ft.

A 100-rem dose is not incapacitating; nausea might be the only noticeable physical affect. An increase of the total dose to 1000 rem and an accompanying increase of the self-protection limit to 1000 rem/h at 3 ft would still not be incapacitating, although the long-term health effects could be serious or fatal To be a truly incapacitating dose, the dose rate must be increased at least another order of magnitude to 10 000 rem/h at 3 ft (incapacitating dose will be discussed later). As a reference, measurements of irradiated fuel have been made at the University of Michigan and the University of Virginia.[2] Both of these reactors regularly operate at 2 MW. Only six NPRs operate at a higher power level. The highest dose rate regularly measured 3 ft from an irradiated element in air was about 2000 rem/h 1 month after the reactor shut down. After approximately 2 months, the element had decayed below 1000 rem/h. Apparently, almost no NPRs could maintain fuel at 10 000 rem/h, and only a few can irradiate fuel to give a dose of 1000 rem/h at 3 ft a few months after shutdown.

Task 3. The Technical Feasibility of Providing Tamper-Proof Radiation Detection to Prevent the Theft of Irradiated NPR Fuel

A tamper-proof radiation detector should have the following characteristics.

(1) Alarm at an off-site location if the radiation exceeds a preset level

(2) Alarm at an off-site location if an attempt is made to change the alarm set point or to disable the device

(3) Not be readily shielded

(4) Not interfere with the normal operation of the facility

(5) Offer an advantage to NPR operations as compared to maintaining fuel at 100 rem/h

Additionally, there must be a guard force that will respond to the alarm.

Approximately one dozen companies were asked about the availability of radiation monitors that give an off-site signal and will alarm if an attempt is made to disable the device. Of the six that replied, two or three have on-the-shelf devices that, with slight modifications, will meet the requirements. The devices include internally set alarm points that can be easily modified to alarm if the set point is changed. These radiation detectors can be purchased for approximately $2000.

Most NPRs are in large, high-ceilinged buildings. A radiation detector could be mounted on a high wall or on the ceiling in an area where local shielding for the detector would be difficult to construct. Shielding the detector would require an insider's knowledge of its location, the alarm set point, and the activity of the fuel. In addition, local shielding (shadow) would be rendered ineffective by scattered radiation.

Most NPRs have radiation monitors in reactor rooms and fuel storage areas. These monitors are designed to indicate high radiation levels and will alarm unless their set points are changed during special operations such as manipulations of fuel or radioactive samples. Typically, these monitors are set to alarm at 10 to 100 mrem/h and are located at reactor floor level.

A detector 30 ft above floor level set to alarm at 10 to 100 mrem/h should not be inconvenient during normal operations. Specifically, a source at ground level that gives a dose rate of 1 to 10 rem/h at 3 ft would be required to trigger this alarm. Lower set points could also be used. The proposed irradiation history described in Sec. II, Alternative 5 gives this dose rate.

A tamper-proof radiation detector alarming at a security office is an improvement over intrusion alarms and motion detectors because the radiation detector will not allow a defeat of its purpose at the site. Motion detectors and intrusion alarms can be turned off with key switches at the site, whereas tamper-proof radiation detectors cannot. There may be cases when the facility operator wishes to deactivate the radiation detector. This action could be accompanied by a coded phone call (with a call back) to the off-site security office and be allowed only during normal working hours. Thus a new and different level of security can be provided by a tamper-proof radiation alarm.

Task 4. Evaluation of the Physical Separability of Fuel Elements Before the Theft of Various NPR Fuels

In this case, physical separability refers to the breakdown of a fuel element assembly into fuel elements, each of which would give a lower dose rate than the whole. The chemical dissolution of fuel is not considered. Three principal items are of concern:

(1) plate-type fuel element assemblies normally containing 10-20 plate-type fuel elements, each swaged into end pieces;

(2) four-rod cluster TRIGA fuel assemblies; and

(3) special containers that may be constructed to contain elements that do not meet the self-protection criteria.

In some cases, a facility may have lightly loaded irradiated elements (control-rod fuel or special experimental elements) that cannot be made as radioactive as normal elements. To meet the 100 rem/h criterion for the container as a whole, these elements may be assembled with a more radioactive one in a special container that is not easily separable.

In all cases, to achieve significant dose reduction, the fuel element assembly must be separated underwater, and the fuel plates or rods removed individually. This would require the design of special tools that could impart significant forces to fuel assemblies while operating under water. For example, in the TRIGA four-rod cluster, the top of each pin is supported by a spacer that is bolted in place, and each pin is screwed into a bottom plate. Two bolts must be removed, and each pin must be unscrewed.

A significant point about the separability of the fuel in an element is not whether it can be done, but what is gained by the adversary. He does not gain a reduction in dose to himself because, although each piece is not as radioactive as the whole, he must handle many more pieces. The time to remove the fuel will be increased, and the total dose will remain essentially the same. Furthermore, the possibility of detection by the reactor facility security force is increased because the time spent in the facility will be increased by the actions of separating and handling the pieces.

In our opinion, to disassemble fuel element assemblies is not practical. Disassembly would neither make the fuel significantly easier to handle nor lower the dose. Separating the fuel elements remotely would also be very difficult and could significantly increase the time for the theft.

Task 5. The Appropriateness of Using Radiation Level Based on a Deterrence Rather Than an Incapacitating Dose

Deterrence is difficult to quantify. An adversary group would be uncertain about the activity level of the fuel, the dose the group will receive, and the effect of the radiation on the group. That radioactive fuel can be a powerful deterrent is shown by public concern when even small amounts of radioactivity are released from power plants. This feeling is likely to be present to some degree in the adversaries, and the knowledge that the fuel was irradiated in recent months could be a sufficient deterrent. If we give the adversary the intelligence to perform the theft, we must also give him the intelligence to be aware of the radiation level and the physiological effects of the radiation.

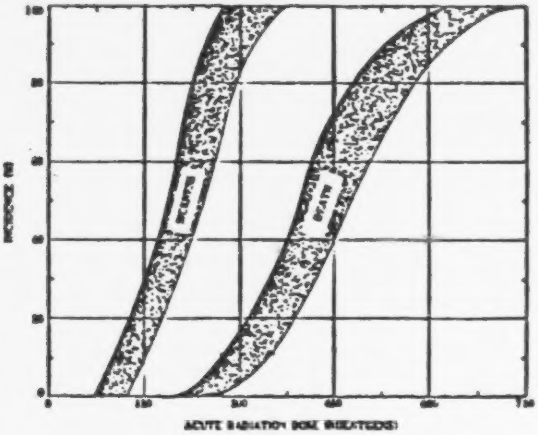

Fig. 1. Radiation dose vs effect.

The dose required to produce death or some degree of radiation sickness in a given percentage of individuals irradiated is shown in Fig. 1.[3] The doses are given in roentgens, but for all practical purposes can be given in rads, as the errors associated with the curves exceed the difference between the exposure and absorbed doses. The reference is 20 yr old, but still reflects the present day thinking on the acute radiation syndrome.

The dose required to cause death in 10, 50, and 90% of those irradiated is approximately 300 R, 450 R, and 600 R, respectively. These doses are referred to now as the LD-10_{30}, LD-50_{30}, and LD-90_{30} doses. With the now accepted value of 500-600[3,4] rem for LD-50_{30}, but the still-accepted value of 300 rem for LD-10_{30}, these curves have too large a slope, and the LD-50_{30} and LD-90_{30} values should be shifted upward by 50 to 100 R.

TABLE I

EXPECTED EFFECTS OF ACUTE WHOLE-BODY RADIATION DOSES

Acute dose (roentgens)	*Probable effect*
0 to 50	No obvious effect, except possibly minor blood changes.
80 to 120	Vomiting and nausea for about 1 day in 5 to 10 percent of exposed personnel. Fatigue but no serious disability.
130 to 170	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25 percent of personnel. No deaths anticipated.
180 to 220	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 50 percent of personnel. No deaths anticipated.
270 to 330	Vomiting and nausea in nearly all personnel on first day, followed by other symptoms of radiation sickness. About 20 percent deaths within 2 to 6 weeks after exposure; survivors convalescent for about 3 months.
400 to 500	Vomiting and nausea in all personnel on first day, followed by other symptoms of radiation sickness. About 50 percent deaths within 1 month; survivors convalescent for about 6 months.
550 to 750	Vomiting and nausea in all personnel within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100 percent deaths; few survivors convalescent for about 6 months.
1000	Vomiting and nausea in all personnel within 1 to 2 hours. Probably no survivors from radiation sickness.
5000	Incapacitation almost immediately. All personnel will be fatalities within 1 week.

The various sickness symptoms produced at lower doses are shown in Table 1.[3]

The term "incapacitating dose" is poorly defined. Several authors state that the acute radiation syndrome does not incapacitate until the acute dose reaches approximately 5000 rad.[4-6] Even at this level, we have no guarantees that a person would not be able to complete his assigned task. In several cases individuals received acute doses of this level or higher and did not immediately become incapacitated.[7]

(1) LASL, August 1945. A reflector was being stacked around a plutonium core when one of the pieces slipped, making the assembly superprompt critical. A burst of 10^{16} fissions gave the worker an exposure of approximately 800 rd. The worker unstacked the assembly, making it subcritical. He died 28 days later.

(2) LASL, May 1946. A beryllium-reflected plutonium metal system was being demonstrated to several people. The upper beryllium hemisphere slipped, giving a fission burst of 3×10^{15} and giving the operator a dose of approximately 900 rd. The worker was not immediately incapacitated, but died 9 days later.

(3) LASL, December 1958. While a physical inventory was being performed on a plutonium solution process line, the solution became reflected when a mechanical stirrer rearranged different stratified phases into a critical configuration. The system became superprompt critical, releasing approximately 4×10^{17} neutrons. A worker received approximately 12 000 rd. Whether he was immediately incapacitated is unclear, but he died 36 h later.

(4) Wood River Junction, July 1964. A concentrated uranyl nitrate solution was hand-poured into a geometrically unsafe container at the scrap recovery plant. A burst of 10^{17} fissions gave the worker a dose of 10 000 rd. The worker was knocked to the floor, but got up and ran from the area to an emergency building 200 yds away. He died 49 h later.

(5) Vinca, Yugoslovia, October 1958. The accident occurred during a planned subcritical operation of the unreflected natural uranium-heavy water critical facility. The detecting chambers had saturated, and the assembly power increased undetected to a very high level. Six workers received doses of 400, 700, 850, 850, 850, and 1100 rd. They were not immediately incapacitated. The worker receiving 1100 rd died; the others survived. All of these individuals were treated medically using specialized blood transfusion techniques.

In an article in Scientific American[6] on the neutron bomb, Kaplan discusses the concept of incapacitating dose as follows.

Radiation doses are measured in rads, 1 rd being the absorption of 100 ergs of energy per gram of any material. If tactical nuclear weapons are to be useful in a war, they must kill their intended victims as quickly as possible. Immediate permanent incapacitation, according to recent US Government tests conducted with mammals, requires 8000 rd. Because modern tanks have a radiation-protection factor of roughly 0.5, tanks must be exposed to 16 000 rd in a short period of time. However, the NATO military doctrine has recently been revised to read that "immediate transient incapacitation," which requires only 2500 to 3500 rd (or, given tank protection, 5000 to 7000 rd), may be sufficient to neutralize invaders for military purposes.

Within 5 min, a person exposed to 8000 rd is incapacitated, and he remains incapable of performing physically demanding tasks until his death, which occurs within 1 or 2 days. A dose of 3000 rd also incapacitates a person within 5 min, but the victim may partially recover within 30 min; however, the dose is still fatal and he will die 4 to 6 days later. Although he may also remain helpless, he may not. These values are consistent with those observed in the Stratton document.[7]

Apparently, to have close to an immediately incapacitating dose, the dose rate per element must reach at least several thousand rem per hour at 3 ft. Based on the examples cited earlier from Stratton's document, a dose rate of 10 000 rem/h would probably be necessary to assure this. We previously noted that increasing the defined self-protection value above 1000 rem/h at 3 ft would be beyond the capability of nearly all NPRs for any significant decay times. Therefore we conclude that we must consider a radiation level based on deterrence or on detection rather than on an incapacitating dose.

Task 6. Estimation of the Quality and Quantity of SNM That Will be Allowed Relative to the Definition of Formula Quantity

As indicated in 10 CFR Part 73, the regulations apply to "any site or contiguous sites subject to control by the licensee who possesses uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope), uranium-233, or plutonium alone or in any combination in a quantity of 5,000 grams or more computed by the formula, grams = (grams contained in U-235) + 2.5 (grams U-233 + grams plutonium)."[1]

The formula puts the same significance on 20% enriched fuel as it does on 93% enriched fuel. During the NRC/NPR licensee meeting held at the University of Michigan in September 1978, Koelling [8] showed the variation of critical mass with enrichment. The functional relationship between critical mass and enrichment has also been well documented in other sources.[9,10] A very close function has been previously used by the NRC in its definition of "effective kilograms." There is little doubt that this variation should be used in any criterion related to the construction of a critical device.

In the regulations, the dose level is given without reference to the quantity of ^{235}U. The formula quantity of 5 kg of SNM and 100 rem/h at 3 ft are not connected in any way. Five kilograms with a dose rate of 100 rem/h are treated in the same manner as ten 0.5 kg sources, each with a dose rate of 100 rem/h. In the latter case, a person would have to handle all of the pieces of SNM and be exposed to 10 times the dose that would be involved in the former case. Therefore the amount of fuel per fuel element should logically be considered in the self-protection criterion.

II. ALTERNATIVES

A. Exemption Based on Integrated Dose

A rule can be written that would allow each facility to demonstrate that an adversary would receive a specified integrated dose while removing a certain quantity of fuel. The greatest advantage of this rule is that it could be written to allow flexibility in dose estimates based on the facility design. Considering the wide differences in facility design, the rule would be advantageous for those sites having a large distance between the fuel and the location of the removal vehicle. The dose received by an adversary depends on this distance as shown earlier. If a licensee wished to increase the time needed for transfer, barriers, doors, or any other hindrance could be used instead of increasing the distance.

The integrated dose alternative has very little physical significance. This dose could be based on the amount of radiation required to trip an alarm, a dose required to give the adversary a variety of physical symptoms, or an incapacitating dose. These options range in dosage from approximately 1 rem up to 10 000 rem, although the higher values would be very difficult or impossible to obtain in NPRs.

In addition, if the integrated dose was set at a level that produces higher absorbed doses than those given for the current fuel dose-rate scenarios, the higher level would strongly conflict with the As-Low-As-Reasonably Achievable (ALARA) rule. In fact, the self-protection rule and the ALARA rule are in conflict at any level.

B. Exemption Based on the Detection

A rule can be written that will allow each facility to ensure that an alarm signal will be transmitted to a security force if exempted fuel is moved from the facility. The alarm signal can be triggered by any one of several actions such as a high radiation signal, motion of a crane that is required to move shielding blocks, motion detectors, intrusion alarms, and so on. The facility must demonstrate that the alarm signal cannot be overridden by the adversary group.

We reemphasize that a tamper-proof radiation detector alarming at a security office is an improvement over intrusion alarms and motion detectors because the radiation detector will not allow a defeat of its purpose at the site.

A facility may also use other detection methods. For example, some NPRs keep fuel in shielded storage pits or in reactors that are encased in concrete. Access to these areas requires that massive concrete blocks be moved with a facility crane. It would be easy to lock out the crane or to provide a signal that will alarm in a security office if the crane is moved during off hours, which would provide an adequate deterrent. Provisions would be made to prevent the use of a portable crane by the adversary group. This should not be difficult because the use of a portable crane would extend the time the group spends in the facility and would probably require using a large access door. Each facility would be required to prove that the proposed system is adequate to allow exemption of the fuel.

Other facilities might use intrusion alarms, motion detectors, and so on. The facility must demonstrate that the alarm system it uses is tamper-proof.

C. Retain the 100 rem/h Exemption but Give Credit for Fuel Enrichment and Mass

The rule as it is now written makes no provision for fuel form, enrichment, or the connection between the dose rate and the quantity of fuel. The fallacy implied in this omission is that the dose to an adversary group would be the same if it had to move many elements, each reading 100 rem/h, as if it had moved only a few elements at the same dose rate.

This can be corrected by making the exemption specific to fuel loading and uranimum enrichment. An example would be to exempt fuel by a formula based on the nominal reactor used in Sec. I :

$$\frac{100 \text{ rem/h}}{175 \text{ g}} \times E^2 = 0.57 \text{ m}E^2 \text{ rem/h at 3 ft} \quad ,$$

where E is the fractional enrichment ($1/E^2$ is the approximate slope of the critical mass versus enrichment curve),[9] and m is the ^{235}U mass in grams with a nominal fuel element mass of 175 g. This formula would not significantly change the requirements for some facilities. As an example, for 165-g elements with a 93% enrichment, the dose rate for exemption would be 81 rem/h at 3 ft. The total dose to an adversary group would not be significantly altered with this change, that is, the most likely dose to an adversary would be about 50--100 rem as noted in Sec. I.

This alternative has the advantage of including fuel form in the regulations. It has the disadvantage of penalizing some facilities with greater than 175-g fuel element loadings (shown in Sec. III) by requiring greater than 100 rem/h for their fuel. However, this alternative is also based on the 100 rem/h number, which has no justifiable physical basis in this case. Fuel more radioactive than that which gives a dose rate of 100 rem/h at 3 ft would clearly increase the hazard when spent fuel must be shipped. This problem can be avoided by placing an upper limit, such as 100 rem/h, on all fuel.

D. Retain 100 rem/h Exemption as Presently Specified in 10 CFR 73.67(b) and 10 CFR 73.6 (b)

The obvious advantage of retaining the present 100 rem/h rule is that no action is required. Many NPRs have adjusted their inventories and procedures to accommodate the rule and assume that they will remain in Category II or III. Some have done this by returning fuel to the Department of Energy (DOE) so that their inventories are less than 5 kg, and others have instituted procedures to irradiate and shuffle fuel and measure dose rates.

Retaining the 100 rem/h rule as it is has three obvious disadvantages:

(1) it will retain a rule containing a numerical value that has no physical basis,

(2) it is inconsistant with the ALARA philosophy, and

(3) it increases the potential hazard to the public in the event of sabatoge more than some of the other choices.

The 100-rem/h value was apparently chosen as a deterrent with the idea that an adversary group would receive a sufficiently high dose that it would not be able to complete its mission of removing the fuel. We developed scenarios in the Phase I report in which the most likely total dose to a group is about 100 rem. This dose distributed among several people is not great enough to impair the actions of the group, that is, 100 rem will not make the persons sick enough so that they could not complete the job in a reasonable time. Thus 100 rem/h, although it may be a psychological deterrent, would not be a physical deterrent. To be a physical deterrent to a group of people, the total dose would have to be approximately 10 000 rem, which would necessitate 10 000-rem/h fuel, a level that (as pointed out earlier) no NPR could maintain. Thus retaining the rule would retain a number that has no physical basis and is just a psychological deterrant.

Maintaining reactor fuel with the present self-protection radiation level of 100 rem/h at 3 ft is difficult at many NPRs. Although many facilities have adapted their procedures to keep fuel self-protecting, these procedures involve increased manipulation of fuel and operational schedules designed primarily to keep fuel radioactive. The rule presents particular problems when spent fuel must be shipped. The best time to ship fuel is when its radioactivity level is as low as possible. Under the 100-rem/h rule, it must be shipped before it is allowed to decay below this level. These actions, which require manipulation of very hot fuel, are inconsistent with the NRC-mandated ALARA program. As pointed out earlier, this inconsistency becomes greater if the self-protection level is raised.

The 100-rem/h rule requires that reactors maintain a large inventory of radioactive fission products. In the event of sabatoge, those fission products could be released to the surrounding environs. To minimize the hazard to the public, a facility should keep the fission product inventory as low as possible, which is inconsistent with the present self-protection rule.

E. Exempt Irradiated Fuel

At one time 10 CFR 73.50 exempted all fuel that had been irradiated in a reactor. An exemption for any fuel that had been in an operating reactor has little physical basis. However, an exemption for fuel that has been irradiated to a minimum specified level may be justified in the sense of deterrence. It is a psychological deterrent to an adversary group to know that the fuel is radioactive. However, we do grant that this psychological effect has not been felt as strongly in adversary groups as it has in the general public. An important aspect of the deterrence factor or irradiated fuel is the uncertainty of the effect of the dose on the people involved. Irradiated fuel in a storage area usually contains elements with various irradiation histories. Typically, there will be fuel that is very radioactive and older fuel that has decayed considerably. This mixture causes the total dose a group would receive to be uncertain and is a deterrent to the group.

A proposed exemption for irradiated fuel is exempting all fuel that has been operated in a reactor for at least 1.5 MW-days/kg of ^{235}U in the previous 12 months. The effect of this value will be shown in Sec. III. The 1.5 MW-days/kg provides a radiation level of 1--10 rem/h at 3 ft as described in Sec. I, Task 3.

The principal advantage of this alternative is that it will not require that dose rates be measured. Any time fuel is moved, there is an additional risk of radiation exposure. This is consistent with the ALARA philosophy because it minimizes fuel handling and the possibility of radiation exposure to personnel. This alternative will allow fuel to cool below the 100-rem/h level and reduce the hazard to the public if a sabatoge attempt is made.

Note that although the dose rate may be lower under this proposal, the fuel will still be radioactive, which will help in the recovery of the fuel if it is removed from the facility. Although the dose rate from a single element is less, the dose rate from the number of elements needed to constitute a formula quantity will be significant with respect to detection and recovery.

III. EFFECT

To determine the effect of a change in the regulations, each facility should be considered in detail. We will make some general statements about each of the alternatives and their effect on a few reactors.

A. Exemption Based On Integrated Dose

A general statement about the effect on individual facilities cannot be made without specifying an integrated dose. Even if the rule was specified, the calculation of the integrated dose would be site-specific and beyond the scope of this report.

B. Exemption Based on the Detection of the Movement of Irradiated Fuel

A general statement about the effect on facility operation cannot be made because each facility would select the mode most appropriate for detecting the movement of fuel. This approach should be more in accordance with the ALARA philosophy and have a positive effect on the sabotage threat because in all probability it will allow lower radioisotope inventories. However, it might involve a capital outlay of several thousand dollars for many facilities.

C. Retain the 100 rem/h But Give Credit for the Mass of ^{235}U per Fuel Element and the Fuel Enrichment

The effect of the formula 0.57 $m E^2$ rem/h at 3 ft, where m is the grams ^{235}U per fuel assembly and E is the fractional enrichment, has been shown for several types of reactors, and the results are summarized in Table II. The dose rate increases in most of the cases.

TABLE II

EFFECT OF CREDIT FOR QUALITY AND QUANTITY OF FUEL

Reactor	Mass of ^{235}U per fuel assembly (grams)	Enrichment (%)	Calculated Dose[a]
Georgia Tech	190.0	0.93	94.0
Virginia Polytechnic Institute	265.0	0.90	122.0
U. of Virginia	170.0	0.93	84.0
U. of Michigan	140.0	0.93	69.0
National Bureau of Standards	250.0	0.93	123.0
U. of Missouri (Columbia)	780.0	0.93	384.0
Washington State U.	510.0	0.70	142.0
U. of Wisconsin	460.0	0.70	128.0
Texas A M	500.0	0.70	140.0
M I T	450.0	0.93	222.0
Oregon State U.	550.0	0.70	154.0
Union Carbide Corporation	200.0	0.93	99.0

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[a] Dose 0.57 mE^2 rem/h at 3 ft

D. Retain the 100 rem/h as Presently Specified

The effect on individual facilities may be significant, although many have adapted to the rule. The effect on one facility, the University of Virginia, is included in Sec. V. This would conflict with the ALARA philosophy, and it would have a significant effect on sabatoge and should be examined closely.

E. Exempt Irradiated Fuel

The effect of exempting all fuel that has been operated in a reactor for at least 1.5 MW-days/kg of ^{235}U/yr has been determined for several reactors. The numbers are given in Table III. The only reactor that would immediately be affected is the reactor at Virginia Polytechnic Institute (VPI). For all other reactors considered, the normal number of full-power days per year of operation exceeds the requirement for at least 1.5 MW-days/kg of ^{235}U/yr.

TABLE III

EFFECT OF EXEMPTING IRRADIATED FUEL

Reactor	Power (MW)	Core Loading (Kg ^{235}U)	Normal Operation Full Power Days/Yr	Required Operation[a]
Georgia Tech	5.0	3.01	87	1
VPI	0.1	3.19	42	48
U. of Virginia	2.0	3.3	83	3
U. of Michigan	2.0	4.5	238	3
National Bureau of Standards	10.0	5.7	283	1
U. of Missouri (Columbia)	10.0	6.2	325	1
Washington State U.	1.0	6.7	38	10
U. of Wisconsin	1.0	8.0	Not Available	12
Texas A & M	1.0	8.62	100	13
MIT	4.9	9.0	204	3
Oregan State U.	1.0	11.17	21	17
Union Carbide Corp.	5.0	5.0	325	2

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[a] $\text{Required Operation} = \dfrac{1.5\ \text{MW - days}}{\text{kg}\ (^{235}\text{U})\ \text{- year}} \times \dfrac{\text{kg}\ (^{235}\text{U})}{\text{Power MW}}\ \dfrac{\text{Full-Power Days}}{\text{Year}}$

IV. EFFECT OF NOT RETAINING AN EXEMPTION

As long as the 5-kg formula quantity value is retained for Category I facilities, an exemption must be retained for irradiated fuel. Some nominal core loadings discussed in an American Nuclear Society text[11] are listed below.

Reactor	Core Loading (Kg)
Union Carbide Corp.	5.0
Georgia Tech	3.0
VPI	3.2
U. of Virginia	3.3
U. of Michigan	4.5
National Bureau of Standards	5.7
U. of Missouri (Columbia)	6.2
Washington State*	6.7
U. of Wisconsin*	8.0
Texas A & M*	8.6
MIT	9.0
Oregon State*	11.6

As is evident from this list, many facilities would be forced to shut down or provide security at the Category I level if an exemption is not retained. Note that the exemption is not used to reduce the level of security to irradiated fuel to a degree less than required by 10 CFR 73.67.

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*TRIGA FLIP fuel, 70% enriched.

V. EFFECT OF MAINTAINING 100 REM/H AT 3-FT SELF-PROTECTION ON THE UNIVERSITY OF VIRGINIA FACILITY

A. Possibility of Maintaining Fuel At Exempt Dose Rates

Normally the University of Virginia Reactor (UVAR) fuel (typically 3.3 kg) can be maintained at the specified self-protection dose rate of 100 rem/h at 3 ft with the present operating schedule. However, there are some cases when this may not be practical. These are discussed below.

The CAVALIER fuel (presently 2.27 kg) cannot be self protecting. Therefore less than 3 kg (a normal UVAR fuel loading) of excess nonexempt material can be maintained on site.

Apparently, fuel can normally be maintained at self-protecting dose rates to limit the nonexempt inventory to less than 5 kg. However, this may cause operational difficulties and increased radiation exposure to personnel as discussed below. In addition, if the UVAR core is allowed to decay to less than self-protecting levels, it will exceed the allowed 5-kg limit.

B. Cases Where It May Not Be Possible To Maintain Fuel At Self-Protecting Dose Rates

1. Prolonged Reactor Shutdowns. As noted above, the present UVAR operating schedule is adequate to maintain fuel at self protecting dose rates. However, a prolonged reactor shutdown may result in fuel decaying to lower dose rates, so that the fuel is not exempt. A prolonged reactor shutdown could occur for many reasons, but the most likely would result from the failure of required equipment or systems.

To minimize this possibility, the reactor facility would be required to stock many additional components, such as nuclear instruments and control-rod drive mechanisms, so that any failures could be quickly repaired. We estimate that an additional $30 000 would be needed to provide adequate assurance that the required long-lead-time equipment was in stock. Even in this case other unforeseen items (such as a major pool leak) might occur that could not be quickly corrected.

2. Delays in Shipment of Expended Fuel. There is a possibility that a spent-fuel shipping cask could not be scheduled before the fuel decays below the self-protecting levels. The availability of shipping casks is, at best, uncertain. If there is any reactivity remaining in the fuel, it could be reloaded and irradiated. This procedure would take about 1 week, which would interrupt ongoing research programs. In addition, the increased personnel radiation exposures and shipment costs associated with shipping of self-protecting fuel make it undesirable to maintain the specified dose rates during shipment. This is discussed below.

3. Receipt of New Fuel. Receipt of new fuel may be more limiting than the availability of a shipping cask for fuel shipments. The CAVALIER reactor has a loading greater than 2 kg of unprotected fuel. If a new core with more than 3 kg were delivered, the formula quantity would be exceeded until the new core was irradiated. Note that CAVALIER fuel and UVAR fuel are not normally interchangeable. The CAVALIER fuel has flat-plate elements, and new UVAR fuel contains curved plates. Thus the CAVALIER fuel cannot be made self protecting by moving it to the UVAR because of its incompatibility.

4. Lightly Loaded Elements. Some fuel elements have lower uranium loadings than others. For example, the control rod fuel elements contain only

half as much uranium as the normal elements. These elements will decay below the self-protection levels before the rest of the core decays. This is a particularly serious problem because the process of connecting and disconnecting the control rod follower to the fuel is complicated and involves a considerable manipulation of the fuel. The operation increases the possibility of radiation exposure to personnel and conflicts with the ALARA philosophy.

5. Imperfect Fuel Elements. Some fuel elements develop fission product leaks that prevent their further operation in the core. When these elements decay below self-protecting levels, they cannot be reirradiated. To ship even a single element from a reactor requires a shipping cask and the associated security measures (at an estimated cost of about $20 000, which does not include the increased security cost noted below).

C. Effect of Maintaining Fuel At Self Protecting Dose Rates on Normal Reactor Operation

Because UVAR fuel can normally be maintained at self-protecting levels, this requirement affects the reactor operating schedule, manpower requirements, and associated costs.

The normal reactor operating schedule is adequate to maintain the control rod fuel elements at self-protecting dose rates for at least 4 months after they are removed from the reactor. This time depends on the actual operating history of the fuel. Thus the control rod fuel elements must be changed about three times a year to ensure that both sets are maintained at self-protecting levels. Because of the fuel loading procedures, this requires complete removal and replacement of the core, calibration of the control rods, and measurement of rod times.

The core replacement described above requires three people for 1 week. Thus a total of 9 man-weeks of effort and a loss of 3 weeks of reactor operation are required each year to ensure that fuel is maintained at self-protecting levels. In addition, the surveillance items necessary to confirm that fuel is self protecting require an additional 6 man-weeks work per year. This work would cost about $8000/yr and result in the loss of about $20 000 in research funds per year. Thus the total cost of this requirement is about $30 000/yr.

In addition, the extra handling of fuel will increase the reactor staff's total radiation exposure. Although this increased exposure is expected to be small, it is still undesirable. Also, the extra handling increases the probability of having an incident that could result in a significant radiation exposure or damage a fuel element. Both items should be evaluated from an ALARA viewpoint.

D. Impact of Maintaining Fuel At Self-Protecting Dose Rates During Expended Fuel Shipment

Maintaining fuel at self-protecting dose rates will have a significant effect on the personnel radiation exposures and the cost associated with the shipment of expended fuel.

As the UVAR reactor room crane has a capacity of only 5 tons, a shipping cask to handle spent fuel (typically 12--15 tons) cannot be lowered into the reactor pool. All transfers must be made outside the building. To accomplish this, operators must lower the shipping cask into a 12-ft-diam, 12-ft-high tank of water using an auxilliary crane outside the building. The fuel elements are moved one at a time from the reactor pool in a small handling cask (~ 2 tons) to the outside of the building and lowered into the tank beside the shipping cask. The element is transferred to the shipping cask by using handling tools from the top of the tank.

During previous fuel shipments, the fuel was allowed to decay to low levels before shipment. The measured dose rates directly above the fuel element were about 1.5 rem/h when the fuel was in the small transfer cask. Using this method, the maximum exposure to personnel was about 10 mrem.

If this procedure is used for the next fuel shipment in 1980 and the fuel has dose rates of 100 rem/h at 3 ft, the total radiation exposure would be increased by a factor of about 100 to about 1 rem. About 10 people would be exposed to radiation during this operation.

Although these exposures are within the limits allowed by the NRC, they are above those normally experienced by personnel at this facility and are inconsistent with the ALARA philosophy.

In addition, the NRC has recently issued an interim final rule that requires extensive security arrangements for shipping any amount of fuel if it exceeds the 100 rem/h dose rate. The requirements of this new rule include the use of trained armed guards, notification and approval of the planned route by the NRC and local law enforcement agencies, and so on. Although no formal cost estimate has been made on the additional cost of shipments meeting the new requirements, one shipper estimates that transportation costs will increase by a factor of 2 or 3. Again, the shipment of highly radioactive fuel is not consistent with ALARA-preferred exposures because the radiation exposure to the shipper's personnel and the general public will be increased.

E. Effect of Maintaining Fuel At Self-Protecting Dose Rates During Unusual Occurrences

There can be many additional situations where maintaining fuel at self-protecting dose rates is undesirable, but they cannot be evaluated in detail.

In the past it was necessary to drain the UVAR pool to repair a leak. To minimize the personnel exposure during the repair, some of the fuel was transferred to the hot cell for storage. If this occurred today, storing all of the fuel in the hot cell could be impractical, and the staff's radiation exposure during transfer would be greatly increased. Thus either the allowed radiation exposures would be significantly increased or a prolonged shutdown, as discussed in Sec. V. B., would be required.

A second, greater concern is the effect of sabotage when higher dose rates are involved. The probability of attempted sabotage is as great as the possibility of theft of SNM. Although many of the controls designed to minimize the possibility of theft will also deter sabotage, both situations should be considered when evaluating the desirability of maintaining fuel at high dose rates.

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BY THE COMPTROLLER GENERAL

Report To The
Honorable Gary Hart
United States Senate

OF THE UNITED STATES

Obstacles To U.S. Ability To Control And Track Weapons-Grade Uranium Supplied Abroad

The United States has exported over 16,000 kilograms of highly enriched uranium for use in research reactors in over 40 nations.

GAO learned that the central computerized system used for tracking such exports is incomplete and inaccurate. Intended users also consider it inadequate and unreliable. In addition, three other systems gather information on highly enriched uranium. GAO recommends streamlining and consolidating the information maintained on this material in a more accurate, comprehensive, and flexible manner.

GAO believes that reducing the use of highly enriched uranium is a sound non-proliferation objective. A number of obstacles, however, must be overcome if the conversion of research reactors to non-weapons grade fuels is to become a reality in the next few years. In the meantime, U.S. ability to ensure adequate physical protection of highly enriched uranium supplied abroad is limited and international safeguards of nuclear material need further improvement.

GAO/ID-82-21
AUGUST 2, 1982

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

B-207024

The Honorable Gary W. Hart
United States Senate

Dear Senator Hart:

In response to your July 14, 1981, request we have reviewed the U.S. ability to control and account for highly enriched (weapons-grade) uranium supplied abroad. This report discusses U.S. administrative controls, physical security reviews, international safeguards and the U.S. ability to keep track of exports of highly enriched uranium. This report also addresses the U.S. efforts to develop a non-weapons grade uranium fuel to be used as a substitute for highly enriched uranium.

As arranged with your office, no further distribution of this report will be made for 5 days from the date of issue unless you publicly announce its contents earlier.

Sincerely yours,

Charles A. Bowsher

Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE
HONORABLE GARY HART
UNITED STATES SENATE

OBSTACLES TO U.S. ABILITY TO CONTROL AND TRACK WEAPONS-GRADE URANIUM SUPPLIED ABROAD

DIGEST

Since 1954, the United States has exported more than 16,000 kilograms of highly enriched uranium for use in research and test reactors in 43 countries. Although most of these exports have gone to countries that are not considered proliferation risks, the U.S. Government has been concerned about the large inventories abroad and terrorists' diversion possibilities. About 25 kilograms of highly enriched uranium is generally recognized as sufficient to make a nuclear explosive device.

CENTRAL TRACKING SYSTEM IS INACCURATE AND UNRELIABLE

The Department of Energy's (DOE) central computerized system used for tracking all U.S. highly enriched uranium exported to foreign countries is incomplete and inaccurate. Intended users also consider it inadequate, inflexible, and unreliable. Although DOE has been working to improve the information in the system, it has not used some readily available internal data to help verify the quantities of highly enriched uranium supplied abroad. (See p. 36.)

Although this one system is supposed to provide a central repository for storage and retrieval of information needed to track highly enriched uranium furnished to other countries, DOE and the Nuclear Regulatory Commission have three other information systems to gather data on this material supplied abroad. (See p. 42.) But the need to have four separate systems appears questionable. Considering the costs of the systems and the needs of the users, efforts to streamline and consolidate needed information seem to be warranted. (See p. 44.)

U.S. CONTROLS OVER HIGHLY ENRICHED URANIUM

The United States attempts to regulate and control its exports of highly enriched uranium fuels through three mechanisms--agreements for cooperation, export licenses, and subsequent arrangements made with other countries. The Nuclear Non-Proliferation Act of 1978 expands U.S. criteria for future nuclear cooperation abroad and calls for a U.S. program to renegotiate existing agreements for cooperation.

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AUGUST 2, 1982

Although language in the agreements for cooperation negotiated since 1978 helps establish tighter controls over highly enriched uranium, virtually all present exports of such material are transferred under agreements that have not been renegotiated. (See p. 8.)

Procedurally, U.S. agencies follow essentially the same general export license criteria and review process for subsequent arrangements for the weapons-grade highly enriched uranium as they do for non-weapons-grade uranium used in power reactors. However, U.S. agencies take extra care in analyzing the technical and economic justification for the export of highly enriched uranium. (See p. 8.)

To minimize the risks of having weapons-grade material accumulated abroad, DOE (or its predecessors) has had the authority for years to accept returns of spent highly enriched uranium of U.S.-origin from other nations. However, only a small portion has been returned. According to U.S. officials, factors, such as the minimum charge for accepting spent highly enriched uranium and high shipping costs, may be discouraging some nations from returning such fuel. Moreover, the authority to accept spent U.S.-supplied highly enriched uranium expires in 1982 and a decision on extending it must be made if this practice is to continue. Agency officials advised GAO that plans are underway to extend this U.S. offer. (See pp. 15 and 17.)

LIMITED U.S. ABILITY TO ENSURE ADEQUATE PHYSICAL PROTECTION

In recent years, the U.S. Government has become increasingly concerned with the physical security of highly enriched uranium from theft by subnational groups. The United States has a mechanism for conducting physical security reviews within nations receiving U.S. highly enriched uranium, but there are some limitations in determining the adequacy of physical security systems.

--Some foreign governments have been reluctant to participate in the program and U.S. officials expect future reviews may be rejected by some governments as no longer necessary.

--Some countries have limited U.S. access at their nuclear facilities. Some visits had to be made to "representative" facilities rather than those handling or receiving U.S. materials.

--Intervals between visits to some countries have been as long as 5 years. (See p. 19.)

Nevertheless, U.S. officials believe that the levels of physical security have improved as a result of U.S. initiatives. Moreover, the establishment of an international convention for protecting nuclear materials, particularly in transit, represents a growing effort to establish some universally acceptable standards for physical protection. (See p. 27.)

COMMON SAFEGUARDS PROBLEMS

The problems of safeguarding weapons-grade nuclear materials, including highly enriched uranium, can be significant. The State Department said that the application of safeguards by the International Atomic Energy Agency is uneven for a variety of reasons and the Agency often fails to meet its own goals. (See p. 29.)

It has been generally recognized that bulk handling facilities, such as fuel fabrication and enrichment plants, pose significant safeguards difficulties. During the review, GAO learned that the International Atomic Energy Agency has been able to carry out only 50 percent of its estimated routine inspection effort and that a number of research reactors which use highly enriched uranium, including a few with significant quantities of fuel, were not being visited even once a year. According to the Agency, the approximate time to convert highly enriched uranium into usable material for a nuclear explosive device is 7 to 10 days for unirradiated, pure form, material and 1 to 3 months for irradiated material. (See p. 29.)

For research reactors that were inspected, specific information about the Agency's ability to meet its timely detection goals is not made public. U.S. and International Atomic Energy Agency officials, nevertheless, agree in general terms that the effectiveness of safeguards has been adversely influenced by (1) a limited number of inspectors and (2) a lack of suitable techniques and equipment. To secure sufficient numbers of inspectors and equipment, in the long-term, will require broad financial and political support by member nations. (See p. 29.)

U.S. EFFORTS TO REDUCE HIGHLY ENRICHED URANIUM LEVELS ABROAD

Much of the U.S. non-proliferation policy has centered around minimizing the use of highly enriched uranium. The reduced enrichment program is one of the few concrete U.S. non-proliferation initiatives to gain widespread international support. (See p. 47.)

Notwithstanding the progress this program has made, several factors are hindering the implementation of the reduced enrichment effort. They include: (1) financial constraints on the program, (2) the limited market potential of the new fuel to interest U.S. private sector involvement without continued U.S. Government support, (3) lack of involvement by U.S. research reactor operators, (4) the potential requirement that facilities which convert to the new fuel must be relicensed by the host country, (5) foreign concerns about the reprocessing of the new fuel and safe disposal of the waste, and (6) uncertainty about U.S. willingness to accept the return of spent low enriched uranium. (See p. 49.)

GAO believes that reducing the use of highly enriched uranium is a sound non-proliferation objective, but a number of obstacles will have to be overcome if the conversion to low enriched fuels is to become a reality in the next few years. (See p. 54.)

RECOMMENDATIONS TO THE SECRETARY OF ENERGY

The Secretary of Energy, in conjunction with the Chairman of the Nuclear Regulatory Commission, should streamline and consolidate the information maintained on highly enriched uranium supplied abroad in a more accurate, comprehensive, and flexible manner which meets the needs of the intended users, in the most economical and efficient manner. (See p. 45.)

To increase the accuracy and utility of such a system, the Secretary of Energy should direct that information from other readily available sources be used to verify and reconcile the data on highly enriched uranium exports within the system. (See p. 45.)

As part of the review process relating to the extension and possible expansion of the authority to accept spent research reactor fuel, the Secretary of Energy should also determine the principal reasons why only a small percentage of spent highly enriched uranium has been returned in the past and adequately address the disincentives to some countries in returning such spent fuels. (See p. 18.)

AGENCY COMMENTS

In commenting on the draft of this report, the Departments of Energy and State, the Nuclear Regulatory Commission, and the Arms Control and Disarmament Agency were generally supportive of the thrust of GAO's conclusions and recommendations. They did offer suggestions to improve the clarity and technical accuracy or to provide a more balanced presentation. The report has been modified to reflect their comments which are reprinted in appendices VIII through XI.

In line with the GAO recommendation, DOE is initiating a review to examine the increased integration of the various systems gathering information on highly enriched uranium. (See p. 80.)

DOE commented that it has been actively working to extend the authority to accept spent highly enriched uranium. It is also considering expanding the authority to permit the acceptance of the low enriched uranium fuels currently being developed. However, the Department also recognizes several disincentives to countries regarding the return of spent highly enriched uranium. (See p. 75.)

ABBREVIATIONS

ACDA	Arms Control and Disarmament Agency
DOE	Department of Energy
EURATOM	European Atomic Energy Community
GAO	General Accounting Office
HEU	highly enriched uranium
IAEA	International Atomic Energy Agency
IPELTS	International Programs Export License Tracking System
LEU	low enriched uranium
NMMSS/INMTS	Nuclear Materials Management Safeguards System/International Nuclear Materials Tracking System
NNPA	Nuclear Non-Proliferation Act
NRC	Nuclear Regulatory Commission
RERTR	Reduced Enrichment for Research and Test Reactors
STAMAS	Special Nuclear Material Tracking and Management System
UNSSOD	United Nations Special Session on Disarmament

CHAPTER 1

INTRODUCTION

On July 14, 1981, Senator Gary Hart requested that we undertake an investigation covering certain issues dealing with the U.S. ability to control and account for the use of the highly enriched uranium (HEU) [1] fuel it exports. (See app. I.) In response to his request, this report reviews U.S. efforts to minimize the use of HEU, describes the various U.S. controls over this type of nuclear fuel and the physical security and international safeguards related to it, and assesses U.S. efforts to keep track of its exports of HEU.

HISTORICAL OVERVIEW OF U.S.-SUPPLIED HEU

Since 1954, the United States has exported over 16,000 kilograms of HEU for use in research and test reactors in 43 nations. (See app. II.) This highly enriched uranium has many beneficial uses in research reactors, such as producing radioisotopes for agricultural, medical, industrial, and research purposes; materials testing; and basic scientific research. However, this material is also usable in nuclear weapons and, in irresponsible hands, it could threaten international security. About 25 kilograms of HEU is generally recognized as the amount needed to make a nuclear explosive device.

The potential risk that HEU would be used for nuclear weapons has caused a growing concern as the quantities in use worldwide have increased. In 1977, the United States began to more closely scrutinize exports of HEU, according to DOE. The special sensitivity of HEU has long been recognized, but divergent views have existed over its export.

The "Atoms for Peace" program, proposed by President Eisenhower in 1953 and authorized by the Congress with the passage of the Atomic Energy Act of 1954 (42 U.S.C. 2011), provides the foundation for some of the most important political instruments that the United States relies upon to deter nations from developing nuclear weapons and serves as the basis for intergovernmental agreements for U.S. nuclear exports. It was under these early agreements and the "Atoms for Peace" program that the United States began exporting research reactors in the mid-1950s. These first research reactors used fuel elements containing less than 20 percent enriched uranium, the value considered to be the threshold for weapons-usable material.

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[1] Highly enriched uranium refers to uranium which has been enriched to 20 percent or more in the isotope U-235. However, HEU is typically uranium enriched to 93 percent U-235.

However, the demand for higher specific power created a desire for greater concentrations of U-235 and led to the use of HEU (mostly 93 percent enriched).

In the 1970s, questions were raised about the proliferation aspects of various fuels and fuel cycles. Early in the Carter administration, U.S. officials became concerned over large inventories of 93 percent HEU that had built up overseas. Although most major recipients were not considered proliferation risks, the Carter administration was concerned with terrorists' diversion possibilities, especially at European fabrication plants. As a result, HEU exports were temporarily suspended pending completion of an assessment of U.S. nuclear export and non-proliferation policies aimed at determining appropriate U.S. policy regarding the foreign distribution of HEU.

The Carter administration wanted to limit the amount of HEU around the world but recognized that the United States had certain obligations as the principal supplier of HEU. It also realized that there were economic benefits to the United States in exporting such material and that continuing to supply HEU could further U.S. non-proliferation objectives by persuading other nations to forego the development of their own enrichment facilities capable of producing HEU.

On April 27, 1977, President Carter proposed non-proliferation legislation to the Congress and outlined several initiatives aimed primarily at strengthening controls over U.S. exports of HEU. Specifically, he announced that, in considering whether a nuclear export would be inimical to the common defense and security of the United States, the executive branch would adhere to the following policies:

--Avoid new commitments to export significant quantities of HEU except when the project was of exceptional merit and the use of low enriched uranium (LEU) 1/ or some other less than weapons-usable material was clearly shown to be technically infeasible.

--Require direct Presidential approval for any supply of HEU greater than 15 kilograms.

--Undertake efforts to identify projects and facilities which might be converted to use LEU instead of HEU.

--Take steps to minimize inventories of weapons-usable uranium abroad.

1/LEU refers to uranium which has been enriched to about 20 percent in the isotope U-235 and is generally considered to be non-weapons usable.

The Carter policy held as a centerpiece the conversion of most research reactors from using 93 percent HEU to uranium enriched to 45 percent and, eventually, to 20 percent enrichment in the isotope U-235.

Although most aspects of President Carter's HEU policy remain in effect, beginning in March 1981, export cases involving HEU were no longer routinely referred to the President. On April 7, 1981, the United States informed its major nuclear trading partners of this change, but noted continuation of other export policies and emphasized the continuing importance attached to the programs to convert to LEU.

ASSESSMENT OF RISK

The current and previous administrations have indicated that HEU poses potential proliferation and nuclear terrorist dangers. For example, in April 1976, DOE's predecessor agency (the Energy Research and Development Administration) defined the proliferation risk of HEU as follows:

> "Highly enriched uranium, when it is in its proper form, is suitable for making nuclear explosives. In the usual forms as a chemical compound, a fuel alloy or a fabricated fuel element, HEU is not directly usable in a nuclear explosive device and would require some chemical or metallurgical conversion. Nevertheless, provided the necessary skills and equipment were available, HEU could be converted and fabricated into a form usable in a nuclear explosive device. It is therefore likely to present a target that is considerably more attractive than low enriched uranium. Because it is not highly radiotoxic prior to irradiation,* * * HEU may also be a more attractive target than plutonium for a nuclear explosive application."

In commenting on a draft of this report, agencies said that most HEU abroad is in an irradiated form which is not easily convertible into weapons-usable material and that only a few nations have the reprocessing capability to recover residual HEU from such irradiated fuel. They pointed out that most HEU has been transferred to close allies and/or signatory nations of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and that the remainder is dispersed in small quantities to the other recipients. Considering these factors, they believe that HEU supplied to other countries does not contribute a significant proliferation risk.

Nevertheless, it is commonly accepted that the presence of HEU should be minimized or avoided to the greatest extent practicable. The agencies agree that reducing the use of HEU was a sound non-proliferation objective. President Reagan has called upon the executive branch "to substitute lower enriched fuels for research reactors at the earliest possible time." The executive branch has had a high priority program for the past several years to reduce the HEU inventories abroad and thus improve the proliferation-resistance of related fuel cycles.

According to the Argonne National Laboratory, current worldwide use and inventory levels create a considerable concern that HEU might be diverted for non-peaceful purposes while in fabrication, transport, or storage and, particularly, while it is still unirradiated.

Concerning the proliferation risks and the need for the reduced enrichment program, State and ACDA officials made the following assessment in 1978. HEU involves weapons-usable material at all points of the fuel cycle. Even irradiated research reactor fuel involving the use of 90 percent enriched uranium in significant quantities can pose a substantial hypothetical risk, in that the enrichment level of the residual material is still typically 80 percent or more. The officials added that the relatively greater ease of reprocessing metal in HEU means that only modest reprocessing capabilities--even large hot cells--could produce enough material for one or more weapons per year.

These officials also stated that a single seizure of a significant quantity of HEU by an irresponsible government or terrorist group could have profound repercussions for the security of all nations and would almost certainly have a highly negative impact on all peaceful nuclear activities to the detriment of all nations. Furthermore, the officials said that the dangers are not limited to material located in irresponsible nations. They said that an irresponsible nation, or a sub-national group, might seize material from the territory of the most responsible nation. Thus, they concluded the problem is no respector of the political orientation, social system, location, alliance relation or even nuclear-weapons-nation status of the nation concerned. The officials indicated that to the extent that LEU can be substituted for HEU, it will eliminate the problem.

OBJECTIVES, SCOPE, AND METHODOLOGY

In line with Senator Hart's request, the thrust of this review was to assess the U.S. ability to control and account for its exports of HEU. As specifically requested, the objectives of this review were to:

(1) Evaluate the mechanisms established in international agreements of cooperation for controlling the use of U.S.-supplied HEU fuel and assuring adequate protection of HEU fuel shipments from terrorists.

(2) Assess the ability of the International Atomic Energy Agency (IAEA) to detect diversions of HEU and fissionable materials produced from this fuel, through material accounting techniques and containment and surveillance devices.

(3) Ascertain the rationale for supplying HEU fuel to foreign countries and the possible nuclear proliferation consequences.

(4) Review the implementation and effects of the U.S. programs announced at the United Nations Special Session on Disarmament in 1978 aimed at limiting the use of HEU fuel in research reactors, as well as any U.S. foreign policy initiatives in this area.

(5) Assess the system used by the United States for keeping track of its exports of HEU fuel and any fissionable materials produced from this fuel.

(6) Determine what controls, if any, the United States has over the use of fissionable materials produced from U.S.-supplied HEU fuel or in U.S.-supplied nuclear facilities.

This review was done in accordance with the "Standards for Audit of Government Organizations, Programs, Activities, and Functions." We applied these standards in gathering information from a variety of sources, including the U.S. Government, national laboratories, private U.S. industry, and embassies of foreign nations.

U.S. Government sources

We reviewed records and interviewed officials at the Departments of State and Energy; the Arms Control and Disarmament Agency (ACDA); and the Nuclear Regulatory Commission (NRC).

We also gathered data about HEU returned to the United States from officials at the U.S.-owned Savannah River plant and the Idaho Fuels Processing Facility. From the Department of Energy's Oak Ridge Operations Office, we received information on the U.S. computerized system designed to track the exports of HEU.

National laboratories

U.S. national laboratories are Government-owned, contractor-operated facilities which conduct extensive research and development. To gain insight into the state-of-the-art of safeguards, we contacted officials at Brookhaven, Los Alamos, and Sandia national laboratories. We obtained information on the U.S. program to develop new LEU fuel from officials at the Argonne National Laboratory.

Private U.S. industry

We discussed the U.S. conversion program to LEU with representatives of General Atomics, Atomics International, and Babcock and Wilcox. We also talked with an official at Allied General's Nuclear Fuel Plant in Barnwell, South Carolina, to learn about reprocessing differences between high and low enriched uranium.

Embassies of foreign nations

We met with officials of the French, Japanese, and West German Governments at their respective embassies in Washington, D.C. The purposes of these meetings were to discuss the current status of their programs to convert research reactors to LEU, to learn their views on the U.S. efforts to develop the LEU fuel, and to obtain some perspective on whether such a new fuel would be readily accepted by the world community.

Reports reviewed

In addition, we reviewed a number of other published reports, including the following:

--Annual Presidential Reports on Nuclear Non-Proliferation

--International Nuclear Fuel Cycle Evaluation reports

--1978 U.N. Special Session on Disarmament reports

--Congressional Research Service reports

--Office of Technology Assessment Report on Nuclear Proliferation and Safeguards

--Our previous reports on related issues (See app. III.)

Agency comments

We obtained comments from the Departments of Energy (DOE) and State, NRC, and ACDA on the draft of this report.

We also received technical comments from the Argonne and Lawrence Livermore National Laboratories, as well as DOE's Savannah River Plant and Oak Ridge Operations Office.

The comments offered suggestions to improve the clarity and technical accuracy of the report or to provide a more balanced presentation and we have modified the report to reflect their comments. We also have included the general comments provided by the four agencies in appendices VIII through XI.

Limitations

In conducting our review, we were confronted by two limitations. We believe, however, these limitations do not significantly detract from our evaluation.

--IAEA does not provide member nations with the results of its inspections in a particular nation or any related documents. Thus, this report does not reflect problems associated with a specific nation or facility, but rather includes a general overview of safeguards implementation. In addition (1) we do not have audit authority at IAEA, (2) IAEA does not make public specific information about safeguards implementation, and (3) some information we had hoped to include in the discussion of safeguards over HEU was classified by the executive branch and therefore was not included in this report. We did not obtain IAEA comments on this report.

--DOE has not yet completed verification of the International Nuclear Materials Tracking System for completeness and accuracy. Although we cite data and statistics from this computer system, we recognize its possible shortcomings. (We discuss the difficulties with this system in ch. 5.)

CHAPTER 2

CONTROLS OVER U.S.-SUPPLIED HEU FUEL

The United States regulates and controls its exports of HEU fuels through three mechanisms--agreements for cooperation, export licenses, and subsequent arrangements. The agreements establish the basic framework for U.S. nuclear cooperation, including the initial supply of nuclear material and any subsequent actions. The export licenses, and review process which justifies them, provide the control mechanism to ensure that the provisions of the agreements and applicable U.S. legal requirements are met before material is supplied. Subsequent arrangements regulate transactions, such as supply contracts, retransfers, reprocessing and return of spent fuel.

Although the special sensitivity of HEU has long been recognized, the terms of the recent agreements for cooperation reflect a greater concern for the control of HEU than those previously negotiated. However, efforts to renegotiate existing agreements for cooperation, as called for in the Nuclear Non-Proliferation Act of 1978 (P.L. 95-242, 92 Stat. 120), have been slow, and, thus, more stringent standards for cooperation, as established by the Act, have not reached fruition on a broad front. Virtually all present HEU exports are transferred under agreements for cooperation that have not been renegotiated.

The specific export licensing review process determines (1) whether the United States will provide HEU to other countries, (2) the amount, and (3) the level of enrichment. The statutory export licensing criteria for HEU are essentially the same as those for slightly enriched uranium. 1/ However, U.S. officials indicated that exports of HEU are given a comprehensive interagency review of far greater intensity, including an in-depth analysis of the technical and economic justification for the export, than normally applied to exports of slightly enriched uranium.

Procedurally, subsequent arrangements for HEU are handled in the same way as those for slightly enriched uranium, with one exception. Unlike spent slightly enriched fuel, the United States routinely accepts the return of spent U.S.-supplied HEU from other nations for reprocessing and storage. The stated reason for this is to minimize the proliferation risk of having such weapons-grade material accumulate abroad. However, DOE records

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1/Slightly enriched uranium refers to uranium which has been enriched to 3 to 5 percent in the isotope U-235. It is used in power reactors and is non-weapons usable.

show that only about 7 percent of all HEU exported has been returned as spent fuel. 1/ According to U.S. officials, factors, such as the minimum charge for accepting spent HEU and high shipping costs, may be discouraging some nations from returning such fuel.

The authority to accept spent U.S.-supplied research reactor (e.g., HEU) fuel, unless extended, will expire in December 1982. State and DOE officials commented that they are in the process of revising the regulations, but that several disincentives are hampering the return of this fuel.

AGREEMENTS FOR COOPERATION SET CONDITIONS

Agreements for cooperation are a precondition for export of nuclear material, including HEU, to other nations and, generally, do not legally commit the United States to make such exports. Legal commitments exist only with the conclusion of specific supply contracts and the issuance of specific export licenses for such exports. Certain controls in the agreements are designed to assure both the United States and the recipient nation or group of nations that materials and equipment transferred between the parties will be used for authorized purposes only and will be properly safeguarded. As of February 1, 1982, the United States had agreements with 25 individual countries and 2 international organizations.

Agreements for cooperation are not exactly alike, due to provisions tailored to the needs of recipients, changes in U.S. statutory and regulatory requirements, new international treaties, technological developments, and an evolving U.S. non-proliferation policy. They also differ according to the scope of nuclear cooperation involved. Most agreements cover both research and power applications of nuclear energy; a few older agreements cover only research or power. The duration of the agreements also varies. Early agreements for research applications ran for 5 to 10 years, while agreements for power applications ran up to 40 years. Newer agreements have customarily covered both research and power applications and run about 30 years.

Prior to the Nuclear Non-Proliferation Act (NNPA), the Atomic Energy Act of 1954 had specified that each agreement contain guarantees that safeguards would be maintained, U.S. nuclear exports would not be used for atomic weapons, and materials would not be retransferred except as allowed under the agreement. In practice, agreements in effect in 1978 typically contained controls above and beyond those required by

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1/Minor amounts have been returned in forms other than spent fuels.

the 1954 Act. In 1978 major control provisions common to most U.S. civil agreements included the following:

--Cooperating nations guarantee that (1) material provided under the agreement will not be used for atomic weapons, for research and/or development of atomic weapons, or for any nuclear explosive device; (2) material made available and, in most cases, material produced from supplied material will not be transferred to unauthorized persons or beyond the jurisdiction of the cooperating party except as authorized by DOE; and (3) safeguards will be maintained on such material.

--Enriched uranium may not be supplied in excess of a ceiling specified in the agreement. 1/ A specific technical or economic justification may be required for supplying uranium that is enriched to more than 20 percent because of the suitability of HEU for weapons development as well as for use in reactors.

--The reprocessing of any special nuclear material may be performed in facilities acceptable to both parties upon a joint determination that the safeguards provisions of the agreement may be effectively applied, or with the prior approval of the United States.

The NNPA added six new criteria for agreements to the 1954 Act and expanded three others. (See app. IV.) Some of these changes codify what had been U.S. practice, while others extend controls beyond those in pre-1978 agreements or the new export licensing criteria.

Two of the most important changes involve safeguard requirements and U.S. prior consent rights. A cooperating partner's safeguard requirements regarding U.S. nuclear exports are specified with greater clarity than before, and non-nuclear weapon nation partners must also have IAEA safeguards maintained with respect to all peaceful nuclear activities at the time of the export. U.S. prior consent rights over the reprocessing of spent U.S.-origin fuel are now required in future agreements. (Similar provisions were already part of most existing U.S. agreements.) Furthermore, in future agreements, prior consent rights to be obtained by the United States over reprocessing and retransfers are to be expanded to cover materials used in or produced through the use of U.S. nuclear

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1/On June 18, 1980, a congressional joint resolution lifted the ceilings for low enriched uranium (less than 20 percent) to nations that are party to the NPT.

exports. Thus, under a new agreement, if a nation were to use non-U.S. fuel in a U.S. supplied reactor, it would have to obtain U.S. permission to reprocess or retransfer the spent fuel. Most of the agreements existing in 1978 did not include prior consent rights involving non-U.S. fuel, nor are such rights required under the export licensing criteria established in the NNPA.

Recent agreements for cooperation have included provisions that are, in certain respects, more restrictive than other agreements or than the law requires. For example, agreements for cooperation concluded since 1978 typically limit the quantity of transferred nuclear material, such as HEU, to amounts sufficient for the loading and continuous, efficient operation of reactors or for use in reactor experiments, or for other purposes as agreed by both parties. In cases where HEU supply is provided for, the new agreements (with such countries as Peru and Indonesia) provide that if excess amounts of HEU are accumulated, the United States has a right to require the return of some HEU. Other new agreements (e.g., with Egypt, Morocco, and Bangladesh) do not provide for the transfer of any special nuclear material other than slightly enriched uranium, except for insignificant quantities for certain specified uses. In addition, DOE officials pointed out that in newer agreements, the cooperating nation authorizes IAEA to provide the United States with nuclear inventory data.

Renegotiation progress is slow

The NNPA attempts to expedite the revision of existing agreements, many of which are not due to expire for several years. The law calls on the President to initiate a program to renegotiate existing agreements, or to otherwise obtain cooperating nations' acceptance of the new criteria, and to "vigorously seek" retroactive application of new criteria to previously exported nuclear material or equipment and to special nuclear material produced in or through their use. However, a deadline for completion of the renegotiation program is not specified, penalties are not prescribed for a nation that refuses to renegotiate its agreement, and the new criteria do not affect the authority to continue cooperation under existing agreements.

The renegotiation progress has been slow and much of the task has not been completed. Since the NNPA was passed, previous agreements with Australia, Canada, Indonesia, and IAEA have been revised or replaced. New agreements have been completed with Egypt, Peru, Morocco, and Colombia; and an agreement with Bangladesh has been forwarded to the Congress for its review. However, previous agreements with 15 nations and EURATOM (European Atomic Energy Community) have yet to be revised. (See app. V.)

Nations have been reluctant to renegotiate for various reasons, including concern over U.S. prior approval rights and perceived U.S. "unilateralism" in revising the ground rules for cooperation. Some nations have deferred renegotiation until the United States has revised other agreements. Others have been unwilling to accept international safeguards on all nuclear facilities.

Some U.S. officials also attribute the slow progress in renegotiating nuclear agreements to the lack of a new, more definitive U.S. policy on non-proliferation. According to one official, foreign countries expect the policy will include a relaxation of restrictions. However, the State Department commented that foreign officials have been given no reason to believe that any changes would affect HEU.

According to ACDA, progress in the renegotiation effort is not that germane to a review of the HEU export question. ACDA commented that although it is helpful to have language in the newer agreements that establishes tighter control over HEU, an effective policy for HEU exports had been implemented prior to the beginning of the renegotiation program; and the the policy continues even though virtually all present HEU exports are transferred under agreements for cooperation that have not been renegotiated.

EXPORT LICENSES CONTROL HEU TRANSFERS

According to U.S. officials, export licensing is the principal controlling mechanism for implementing provisions in the agreements for cooperation. As a condition for future U.S. exports of uranium supplies, other parties must continue to comply with the provisions of the agreements.

The NNPA sets forth the general export licensing criteria. As with slightly enriched uranium exports, the transfer of HEU is generally conditioned upon the proposed license's meeting general conditions. Briefly, these conditions require that the export, and in some cases, special nuclear material used in or produced through the use of such export, be subject to

--the terms and conditions of the U.S. agreement for cooperation with the receiving nation or group of nations,

--application of IAEA safeguards (for non-nuclear weapon nations, IAEA safeguards must be maintained on all of their peaceful nuclear activities at the time of export from the United States),

--adequate physical security measures,

--prior U.S. approval for any export retransfers to the jurisdiction of any other nation or group of nations than was initially authorized,

--prior U.S. approval for any reprocessing or other physical alteration of the export,

--prior U.S. approval for any enrichment of the export, and

--a U.S. determination that the proposed export will not be inimical to the national defense of the United States.

Although not set forth in the NNPA as part of the licensing criteria, it is during the export licensing review process that Federal officials

--evaluate the technical and economic justification for any export of 5 or more kilograms of HEU, and

--determine whether a proposed export of HEU has "exceptional merit" before making a new commitment.

Technical and economic justification

In making the required review of proposed HEU exports, U.S. officials [1] review the operation of the reactor proposed to receive the material, the contemplated use of the HEU, and the recipient country's efforts to convert to LEU fuels. Acquiring its information directly from foreign countries for each case-by-case review, the Argonne National Laboratory calculates how much fuel the facility has on hand, how long it should last, and how much more is needed. Based on such analyses, U.S. officials, in some cases, have reduced requested quantities of nuclear materials, deferred shipments, and split applications for fuel into two separate licenses. The United States usually supplies fuel in 1-year increments.

"Exceptional merit" for new commitments is tightly restricted

Under the Carter policy of April 1977, any "new commitments" of HEU--commitments made for facilities or countries which had not received shipments before April 27, 1977--became subject to a finding of "exceptional merit." According to U.S. officials, such a determination is to be based on several criteria:

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[1] Includes officials from the Departments of State, Energy, Defense, and Commerce, ACDA, and NRC.

--The level and type or nature of government involvement.

--Fuel alternatives available, i.e., the need for the reactor in question and its design requirements which necessitate HEU fuel usage.

--The country's non-proliferation credentials.

--The nature of a high-powered research reactor.

In assessing whether the project has exceptional merit, the executive branch is to place more emphasis on the project's programmatic aspects--the purpose, importance, and benefits to be derived from the planned research--than on its economic aspects. It also is to consider whether other operating reactors within the country or in other countries could provide a viable alternative for performing any part of the planned research. Cases which might justify a finding of "exceptional merit" include medical research needs or certain kinds of materials testing requiring high-powered research reactors (about 50 megawatts).

According to State Department officials, the application of the exceptional merit criteria has been a deterrent in the requests for new commitments of HEU. The only "new commitment" licensed since passage of the NNPA was in 1978 for HEU shipments to a reactor at Kyoto University in Japan. This was considered justified because the reactor was designed before the Carter policy was initiated. Although one fuel load of HEU was licensed, Japan agreed to work toward converting to LEU fuels. According to a DOE official, the United States would not authorize any further HEU fuel loadings for this reactor.

SUBSEQUENT ARRANGEMENTS EXTEND CONTROLS

Subsequent arrangements refer to the regulatory controls administered by DOE over certain cooperative arrangements regarding the supply, use, or retransfer of U.S. nuclear material and equipment. Such arrangements include contracts for the sale of enrichment services for HEU and arrangements involving the return of spent HEU to the United States.

Before the United States can approve any proposed subsequent arrangement, the NNPA requires DOE to make a national security determination that the arrangement will not be "inimical to the common defense and security" of the United States. The security finding is a common criterion governing all types of subsequent arrangements. Our review showed that the procedures for most subsequent arrangements involving HEU are essentially the same as those employed for non-weapons-grade, slightly enriched fuels, except for the return of spent HEU fuel. However, U.S. officials assert the nature and intensity of subsequent arrangement reviews are quite different for slightly enriched uranium and HEU.

Pursuant to the Atomic Energy Act of 1954 and Federal regulations, the United States, for years, has routinely accepted the return of limited quantities of spent U.S.-supplied HEU for reprocessing and storage, but not slightly enriched spent fuel. According to DOE records, approximately 1,100 kilograms (about 7 percent of the total U.S.-supplied HEU) have been returned to the United States as shown in the following chart.

Country	Weight in kilograms of returned spent HEU	
	Total element weight	Contained U-235
Austria	3.4	2.3
Belgium	86.6	63.2
Canada	408.2	268.9
Denmark	37.9	25.9
France	408.2	324.6
Germany, West	131.5	93.5
Italy	12.0	9.6
Japan	69.8	61.8
Mexico	.6	.4
Netherlands	105.5	80.4
South Africa	19.0	14.3
Sweden	204.1	153.8
United Kingdom	.4	.3
Total	1,487.2	1,099.0

In commenting on our draft report, the Argonne National Laboratory said that the average fuel burn-up during operations may be nearly 50 percent and the process losses could be nearly 20 percent. Using these figures, the maximum amount that could be expected to be returned is about 4,800 kilograms. Based on such estimates, the 1,100 kilograms returned represent about 23 percent of the total that could be expected to be returned.

DOE is required to recover the full cost for all fuel cycle services rendered to non-DOE customers. As a result, DOE has a minimum charge for accepting and reprocessing spent HEU which reflects an estimate of the cost of providing processing services for small quantities of material. The charge includes process system start-up costs, recovery operations, and plant clean-out for materials accountability. DOE believes it is logical that the per kilogram cost for processing small quantities of fuels is higher than for larger batches because much of the process is insensitive to the quantity of material involved.

According to a Savannah River official, the minimum charge is currently $30,000 plus a charge per kilogram for waste management. He estimated that a country would need to return about 100 kilograms at one time for it to be cost effective. As a result, the minimum charge can act as a disincentive to nations with smaller volumes of spent HEU, according to some U.S. officials. These countries tend to store spent fuel and accumulate it to make the minimum charge economically justifiable. One ACDA official believes it would better serve non-proliferation goals to abolish the minimum charge or adjust it selectively for different countries.

DOE's Federal Register Notice concerning authority to take back and reprocess spent U.S.-supplied HEU expires in December 1982. An ACDA official said it is critical that this authority be extended. He added that it might be desirable to also expand the authority, if possible, to allow for U.S. retrieval of spent foreign-origin HEU fuel. He also said that this would help advance U.S. non-proliferation interests by further preventing spent fuel accumulation in countries' inventories and provide them an alternative to developing their own reprocessing capabilities.

CONCLUSIONS

International agreements for cooperation, export licenses, and regulatory review of subsequent arrangements are the mechanisms by which the United States can control its exports of HEU.

Recent agreements reflect a greater concern for the control of HEU than previous ones. However, efforts to renegotiate existing agreements have been slow and agreements with 15 nations and EURATOM remain to be renegotiated. Virtually all present HEU exports are transferred under agreements that have not been renegotiated.

Procedurally, U.S. officials follow essentially the same general export license criteria and review process for subsequent arrangements for weapons-grade HEU as they do for non-weapons-grade slightly enriched uranium. However, the additional care taken in analyzing the justifications for proposed exports of HEU have resulted in reduced quantities of material being exported and the deferral of shipments in a few cases.

To minimize the risks of having weapons-grade material accumulated abroad, the United States has had the authority for years to accept the return of HEU of U.S.-origin from other nations. However, only a limited amount of U.S.-supplied HEU has been returned. Moreover, the authority to accept spent U.S.-supplied HEU expires in 1982 and a decision on extending it will need to be made during 1982 if this practice is to continue.

We believe that, in general, the practice of accepting spent U.S.-supplied HEU fuel is beneficial to the overall U.S. non-proliferation strategy and should be continued. In our draft report, we suggested that DOE (1) extend the authority to accept spent U.S.-supplied HEU and (2) consider the concerns expressed by U.S. officials that the minimum standard charge for accepting and reprocessing spent HEU acts as a disincentive to some countries.

AGENCY COMMENTS

DOE commented that it has had active plans underway for several months to extend the U.S. offer to reprocess and store U.S.-origin HEU irradiated in foreign research reactors. DOE indicated that the offer would be extended before the current Federal Register Notice expires at the end of 1982. With regard to the minimum reprocessing charge, DOE believes sufficient flexibility exists in U.S. policy to permit several small users to combine their spent fuel into single batches. DOE added that it has encouraged this type of batching in the past and intends to encourage it to a greater degree in the future. Given its obligation to recover its full costs in such activities, however, DOE does not anticipate that it will be feasible to reduce its charges.

In responding to our draft, those commenting raised other issues about accepting spent research reactor fuel. For example,

--The State Department agreed with our suggestion that the authority to accept spent U.S.-supplied HEU be extended. Additionally, State commented that the authority should be expanded to permit the return of the LEU fuels being developed to replace the currently used HEU. Without such a U.S. commitment in the near future, the State Department believes the implementation of the program to reduce the levels of HEU abroad will be significantly delayed. DOE is now considering the incorporation of provisions in the Federal Register

Notice to accept certain types of new fuels and has a study underway concerning the reprocessing of another new fuel.

- --According to the Argonne National Laboratory, the cost of shipping spent HEU from foreign reactors to an assigned DOE reprocessing facility is probably a greater disincentive than the minimum reprocessing charge.

- --NRC commented that on at least one occasion a country was reluctant to return HEU because DOE has no authority to reimburse for the value of reclaimed material and U.S. export policies preclude reimbursement through provision of material-in-kind.

RECOMMENDATION TO THE SECRETARY OF ENERGY

As part of the review process relating to the extension and possible expansion of the authority to accept spent research reactor fuel, we recommend that the Secretary of Energy determine the principal reasons why only a small percentage of spent HEU has been returned in the past and adequately address the disincentives to some countries in returning such spent fuel.

CHAPTER 3

U.S. ABILITY TO ENSURE ADEQUATE PHYSICAL PROTECTION IS LIMITED

Due to the rise in terrorism, generally, and the number of specific assaults on nuclear facilities in recent years, the U.S. Government has become increasingly concerned with the physical security of HEU from theft by subnational groups. Although the United States has a mechanism for conducting physical security reviews within nations receiving U.S.-supplied HEU, a number of problems exist which hinder the effectiveness of these reviews.

There is a fundamental need to gain foreign cooperation in ensuring that adequate physical protection standards are applied. However, the United States sometimes finds it difficult to gain access to foreign nuclear facilities or sections of facilities which will be using U.S.-supplied HEU. In addition, due to sensitivities of national sovereignty, intervals between visits have sometimes been lengthy. Nevertheless, U.S. officials have relied on information from the visits for licensing purposes.

Many countries voluntarily adhere to IAEA's guidelines [1] on physical security and have their own independent reasons for wishing to protect their nuclear installations from dissident or terrorist groups. A group of nuclear supplier nations have also agreed on minimum physical security requirements for exports of HEU. In addition, under a U.S. initiative, an international convention on physical security of nuclear materials has been approved by a number of countries.

CONCERNS OVER NUCLEAR TERRORISM HAVE INCREASED

Terrorists can operate with a variety of purposes which include the theft of nuclear material for use in nuclear explosives, radiological weapons, or resale to finance other operations; sabotage to scare the public and discredit the government or establishment; or extortion to gain concessions such as freeing prisoners. In short, terrorists are interested in those actions that may directly or indirectly cause harm to the public or otherwise undermine government ability to inspire public confidence and to control events.

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[1] IAEA has no statutory basis for conducting physical protection reviews. However, in 1972 and 1975, the IAEA Director General convened a panel of experts which prepared a report containing recommendations on physical protection. The panel report is circulated by IAEA to member nations in connection with their national physical protection responsibilities. U.S. officials indicate that countries do not want IAEA involved in physical security reviews because it would be considered an unacceptable invasion of national sovereignty.

Since the mid-1960s, the United States and other countries have experienced an upsurge in threats and acts of sabotage or violence directed at nuclear facilities. Although such acts may not involve the efforts of organized terrorist groups specifically to divert nuclear materials for the purpose of making an explosive device, the incidents, whatever the motives, illustrate the need for physical security. Between 1966 and 1979, at least 39 physical security incidents occurred at nuclear facilities. (See app. VI for a listing of the attacks and/or physical security breaches at nuclear facilities.) Nuclear terrorist acts have continued through 1982 with the January 19 assault on the Creys-Malville fast breeder reactor under construction in Lyons, France. Although terrorists firing five Soviet-made antitank rockets caused no injuries and little damage, they scored four direct hits on the plant's concrete outer shell, demonstrating the severity of the challenge to physical protection.

As a 1976 U.S. Government report on nuclear export activities said:

> "* * * any vulnerability in the fuel cycle might conceivably be exploited if it could be used for financial return or in some way cause harm to the public, or at least threaten such harm in a way that concessions would have to be made. * * * The physical security * * * system must be based on an assumption that the possibility of a serious threat exists."

U.S. MEASURES TO ENSURE PHYSICAL SECURITY REQUIRE FOREIGN COOPERATION

Since 1974, the United States has promoted a policy of ensuring the physical security of nuclear facilities on a global basis, and has especially required adequate physical security for U.S. nuclear materials sent abroad. The NNPA made the latter a matter of statute. Thus, DOE/NRC teams assess recipient countries' physical security measures before recommending approval or denial of licenses for exports or retransfers of shipments exceeding certain limits, such as 5 kilograms of HEU. Such teams have visited more than 40 countries receiving U.S. nuclear materials and representatives from a number of countries and EURATOM have visited the United States to observe U.S. methods, discuss individual protection problems, and exchange expertise. In addition, special U.S. training programs involving physical security are being carried out for representatives of foreign countries.

Physical security is a sensitive subject internationally, because it is considered to be a matter within a country's domestic jurisdiction. Consequently, some countries limit U.S. access to their nuclear facilities. Nevertheless, in export licensing, NRC and other Federal agencies have relied on the results of these visits to judge the adequacy of physical security measures in the recipient country.

Physical security standards

Although U.S. agreements for cooperation have not previously contained provisions relating to physical security, the NNPA requires that adequate physical security be maintained for any proposed U.S. export of source material, special nuclear material, production or utilization facilities, or special material used in or produced through the use of such material or facilities. However, it should be noted that neither the NNPA nor the agreements for cooperation require that review visits be conducted on a periodic basis.

In accordance with the NNPA's requirements, NRC established levels of physical security which, in its judgment, would be no less strict than the standards established by any international guidelines to which the United States subscribes. NRC regulations specify levels of physical protection based on the potential hazards of the material to be shipped, its type (i.e., plutonium, uranium, thorium), isotopic composition (i.e., content of fissile isotopes), physical and chemical form, radiation level, and quantity. HEU shipments of 5 kilograms or more are given the highest level of protection.

In addition to these regulations, NRC has noted that in evaluating whether the physical security program of a country meets these physical security standards, the Commission staff considers for the most hazardous materials the following essential elements, or their equivalent:

"(i) Storage of materials in areas which provide penetration resistance and delay;

(ii) Protection of processing and storage areas with intrusion alarm system;

(iii) 24-hour armed security forces (or an unarmed security force if a national or regional emergency plan has been established that will ensure immediate wide scale alert and response by armed police or other government agencies);

(iv) Armed offsite forces capable of response;

(v) Independent duplicated transmission system for two-way voice communication.

(vi) Procedures to control access to and to provide continuing surveillance in material storage and processing areas;

(vii) Protection of transport by escorts or guards to be armed if armed emergency teams are not available for timely response to prevent attempted theft and facilitate recovery;

(viii) Transport in vehicles equipped with communications capable of calling for assistance from the local police or emergency team;

(ix) A program for determining trustworthiness of guards and individuals who have access to nuclear materials.

The Commission also notes that the staff will consider any potential threats to nuclear activities within the recipient country."

Physical protection reviews are limited

Although NRC and DOE officials said that sufficient information is obtained during their visits to determine the adequacy of physical security in a country, there are some limitations and problems with the ability of the United States to determine compliance with U.S. requirements.

NRC and DOE review team officials said that the purpose of the visits is to determine if all elements of an "adequate" physical security system are in place. The review, however, is not intended to determine how effectively the physical security system is working. Moreover, NRC and DOE officials do not consider these visits to be inspections but rather part of an "exchange program" whereby the United States and the recipient country share physical security technology and information with each other.

One limitation confronting the United States is that reviews are not always conducted at each facility handling or using U.S. supplies and materials. Because, at the insistence of the recipient country, visits sometimes are made at "representative" facilities, the United States has approved exports destined for facilities declared to have an adequate physical security system even though U.S. officials had never visited them. NRC commented that, under its regulations, determinations may be based upon a country-wide rather than upon a facility specific analysis.

This situation is exacerbated in some countries by limited U.S. access at the nuclear facility. For example, during one Argentine visit, the U.S. review team was not permitted to see part of the facility it wanted to see. A similar situation occurred in the United Kingdom, although this was resolved in a later visit. NRC and DOE officials anticipate that this problem might become more severe during future visits because some countries are questioning the need for additional U.S. reviews.

Another limitation is the lack of current physical security information for some countries. As a result, NRC and DOE are limited in their ability to determine if the integrity of the physical security systems has been maintained since the previous visit. Since 1974, the United States has visited 41 countries, including 37 which have received U.S.-supplied HEU and 4 which have received special nuclear materials other than HEU. Visits have not been made to six nations which have received HEU. 1/

As shown by the following chart, the majority of countries and facilities reviewed were visited during the early years of the program. From the first review in December 1974, the physical protection exchange visits peaked at 38 facilities in 20 countries in 1976. In 1981, only five facilities in two countries were visited as part of this program.

Year of visit	Countries visited	Facilities reviewed
1974	1	2
1975	17	28
1976	20	38
1977	9	15
1978	1	2
1979	3	5
1980	7	17
1981	2	5

1/Bangladesh, Bolivia, Czechoslovakia, Iran, Vietnam, and Zaire. With the exception of Iran, which has received 5.2 kilograms, the others have each received no more than a few grams in total shipments. NRC noted that physical security visit are not required for gram quantity amounts and that the shipment to Iran was made before the United States established physical security requirements for exports.

According to DOE, criteria for initiating visits by U.S. physical security teams include:

1. Political unrest or increased terrorist activity in the country since the last visit.
2. New, or expanded, Category I facilities 1/ under consideration or have been put into operation since the last visit.
3. Significant improvements in physical security have occurred since the last visit.
4. Consideration of the time since the last visit.

The following table shows the number of facilities in each country visited since the review program began and the date of these visits.

Date of visit	Country	Number of sites visited
December 1974	France	2
April 1975	Sweden	1
	Netherlands	1
	West Germany	3
	Italy	3
June-July 1975	Japan	2
	Republic of China (Taiwan)	3
	Philippines	1
	South Korea	1
July 1975	Canada	1
August 1975	South Africa	1
September 1975	Romania	2
	Turkey	1
	Pakistan	1
Oct. - Nov. 1975	Denmark	1
	Sweden	2
	United Kingdom	2

1/A designation in IAEA's physical security guidelines which includes a facility containing 5 kilograms or more of unirradiated HEU.

Date of visit	Country	Number of sites visited
November 1975	India	2
	Yugoslavia	1
February 1976	Japan	1
	Philippines	1
	Thailand	2
	Indonesia	2
	Australia	1
April 1976	Austria	3
	Switzerland	2
	Spain	2
	Belgium	2
	France	2
	Italy	6
June 1976	Argentina	3
	Brazil	4
July - August 1976	Portugal	1
	Israel	2
	Greece	1
October 1976	Finland	1
	Norway	1
	Ireland	1
	Luxembourg	1
July 1977	Japan	2
	Thailand	3
	Malaysia	1
September 1977	Colombia	1
	Venezuela	2
December 1977	Argentina	3
	Uruguay	1
	Paraguay	1
	Peru	1
October 1978	Mexico (note a)	2
October 1979	Netherlands	1
	Belgium	3
	Switzerland	1

a/Visit conducted as part of IAEA support program.

Date of visit	Country	Number of sites visited
Feb. - March 1980	United Kingdom	2
	Denmark	1
	France	2
March - April 1980	Switzerland	3
	Spain	2
November 1980	South Korea	2
	Japan	4
September 1981	Italy	2
	West Germany	3

No future visits planned as of December 1981.

Comparing the table above and a DOE listing of HEU transfers shows some of the limitations previously cited. For example, in 1974 six facilities in France received shipments of U.S. HEU; U.S. review teams, however, visited two facilities deemed to be "representative" of them all, including one which received no HEU that year. In 1980, three facilities in the United Kingdom received U.S. HEU shipments while review teams visited two "representative" facilities.

Also, in some cases (West Germany, Korea, and the Philippines) intervals between visits have been as long as 5 years, thus rendering the currency of previously gathered information suspect. During 1974 and 1978, review teams visited only one country, France and Mexico, respectively. Of 41 nations visited, 15 have been visited more than once. NRC commented that although only 11 countries were visited from October 1979 to September 1981, they accounted for approximately 90 percent of the total HEU exported. In addition, the major foreign fabrication plants, which typically are the initial recipients of U.S. exports of HEU, were visited during this time period. It should be noted, however, that a fabrication plant is only an intermediate stop for the HEU before arriving at the ultimate user's facility.

NRC and DOE officials said that as a result of their reviews, NRC has delayed approving licenses on numerous occasions because of problems found with the physical security program of the recipient country or of a country considered to be an intermediate consignee. Although delays of up to 6 months have occurred in the licensing process, these officials advised us that improvements in the recipient country's physical security program were made and U.S. concerns were resolved as a result of the visits.

CONVENTION ON PHYSICAL PROTECTION SETS GLOBAL STANDARDS

Negotiation of an international convention on the physical protection of nuclear material was completed in October 1979. The Convention, which was opened for signature on March 3, 1980, requires nations to take appropriate steps to protect nuclear material used for peaceful purposes during international transport, and not to authorize the import or export of such material unless assured that it will be protected during transport at prescribed levels of physical protection. It also establishes a framework for international cooperation to recover lost or stolen material, and a system for prosecution or extradition for serious offenses.

U.S. officials point out that the Convention successfully completed a United States initiative to establish a regime of international cooperation to improve the physical protection of nuclear material, and that this achievement constitutes a major step in fulfilling the goals expressed in Titles II and IV of the NNPA. The United States signed the Convention on March 3, 1980, and the Senate adopted a resolution providing its advice and consent to ratification on July 30, 1981. (See app. VI for Convention signatories.)

Administration proposals for U.S. legislation to implement the Convention's criminal provisions were submitted to the House of Representatives and Senate on August 22, 1980, and again on April 7, 1981. As of April 1982, hearings have been held by the Senate Judiciary Subcommittee on Criminal Law, and the House Judiciary Subcommittee on Crime.

CONCLUSIONS

We believe that the increasing awareness of the problem of physical protection of nuclear materials, particularly HEU, is appropriate given the increase in incidence of terrorist activities in recent years. Attacks and breaches of security at nuclear facilities demonstrate the persistent danger of diversion of nuclear materials posed by terrorist groups and the continued need for the United States to ensure the physical security of HEU shipped overseas.

The U.S. physical security reviews, however, have uncertain effectiveness for determining adequacy of protection. Visiting "representative" facilities, or parts of facilities, rather than actual recipients of HEU exports might not adequately demonstrate the measures at the facility, or part thereof, which will actually use U.S.-supplied HEU. Thus, applying information gathered during such reviews to approval of export licenses could, in some cases, result in determinations based on inapplicable data. In similar manner, the sometimes lengthy interval between visits to a country throws into question the validity and timeliness of available U.S.

information. In addition, the reported resistance of certain nations to hosting return visits by U.S. teams threatens the continuation of the review program.

The establishment of an international convention for protecting nuclear materials, particularly in transit, represents a growing effort to establish some universally acceptable standards for physical protection.

AGENCY COMMENTS

DOE commented that in all of the 41 countries visited one or more times, there has been, in general, excellent cooperation. U.S. physical security teams have visited representative nuclear facilities in each country and all facilities in most countries. However, DOE pointed out that countries view physical security as a national responsibility and not one to be executed by the United States or IAEA. DOE feels this is a reasonable position.

According to DOE, the U.S. team has emphasized to each country that the mutual benefits to be derived by an exchange of information would be improved security systems worldwide. The United States has provided suggestions for improvements, when appropriate, and has held up some exports until systems were upgraded to satisfactory levels. DOE believes the results of this program have been encouraging as evidenced by an international awareness and concern of the risks, a willingness to cooperate, and commitments to upgrade programs where needed.

CHAPTER 4

PROBLEMS WITH INTERNATIONAL SAFEGUARDS

IAEA safeguards are aimed at providing timely detection of diversion of nuclear material from peaceful nuclear activities. However, the adequacy of such safeguards has been increasingly challenged in recent months. In general terms, IAEA and U.S. officials admit that IAEA inspectors have experienced some difficulty in meeting the Agency's timely detection goals at the facilities inspected.

During our review, we learned that IAEA has been able to carry out only about half of its estimated routine inspection effort and that a number of research reactors, including a few with significant quantities of HEU, were not being visited even once a year. If HEU were diverted, it could be converted for use in a nuclear explosive device in as short as 7 to 10 days. Details on IAEA's ability to meet its own timely detection goals for HEU at facilities it has inspected are not available to the public.

Nevertheless, U.S. and IAEA officials agree that the general effectiveness of IAEA safeguards has been adversely influenced by several factors, including (1) a limited number of inspectors and (2) a lack of suitable techniques and equipment. To secure sufficient numbers of inspectors and equipment, in the long-term, will require broad financial and political support by member nations.

IAEA DETECTION ABILITY

The objective of IAEA safeguards is to provide

> " * * * timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."

To measure its ability to meet this objective, IAEA established detection goals in 1979 in which it defined a significant quantity of nuclear material as the approximate amount needed to construct a nuclear explosive device. For example, IAEA considers 25 kilograms (about 55 pounds) of contained HEU to be enough to make a nuclear explosive device. According to IAEA, timely detection refers to the ability to identify any diversion within the approximate time needed to convert nuclear material into the fissile component of a nuclear explosive device. For certain forms of HEU that time could be as short as 7 to 10 days. For irradiated HEU, the detection time is 1 to 3 months. According to DOE, IAEA determined that detection goals, such as 25 kilograms, were considered reasonable for a non-nuclear weapon nation because of the difficulties such a nation would have in making efficient use of the material in making a bomb. DOE added that nuclear weapon experts from various nuclear weapon nations, including the United States, advised IAEA on this determination.

In commenting on a draft of this report, ACDA said that IAEA's policy is to inspect every facility at least once a year and that this policy is not dependent on the particular goal being used. According to DOE, research reactors possessing more than a significant quantity of fissile material are inspected with a frequency governed by the size and characteristics of the project, the quantities of unirradiated HEU likely to be involved, as well as the potential for plutonium production. However, our review showed that a number of facilities with HEU, including a few with significant quantities of unirradiated HEU, were not inspected once in a typical year.

The main inspection objective of IAEA safeguards at research reactors is to detect the absence of fuel items (e.g., assemblies, rods, bundles, plates, or pins) containing one or more significant quantities of HEU within the timeliness guideline. However, during any single year, IAEA often does not inspect many research reactors, including some with more than a significant quantity of HEU, because of inspection staff shortages. In addition, IAEA has considered its goals automatically attained when less than a significant quantity of material was reported as being on hand.

STAFFING LIMITATIONS

To fulfill its safeguards responsibilities, IAEA must have the necessary staffing. However, the number of IAEA inspectors has not kept pace with its rapidly growing safeguards responsibilities.

IAEA has been experiencing shortages in its inspectorate staffing for several years. Although there have been major increases in the inspectorate, there has also been a substantial increase in the number of facilities under safeguards. Consequently, IAEA achieves significantly less than its estimated routine inspection effort. This trend has continued, although improving somewhat. According to the State Department, IAEA carried out only about 50 percent of its estimated routine inspection effort in 1981 due to its inspector shortage. The Department indicated that IAEA expects to increase this mark to 60-70 percent by 1983.

Thus, the shortage of inspectors is expected to be a continuing problem. To help offset the lack of regular professional inspectors, the IAEA Secretariat has proposed employing inspection assistants to handle some of the less complex aspects of safeguards.

EQUIPMENT LIMITATIONS

IAEA lacks suitable equipment to adequately make quantitative verifications of nuclear material in many cases. A substantial amount of material, including HEU, is in a form that is currently unmeasurable. According to IAEA officials, further development of methods and equipment for nondestructive measurements of HEU, especially irradiated fuel, at research reactors is still needed.

During a previous review, [1] IAEA officials indicated that only about 10 percent of all safeguarded material is quantitatively measured. Material inside reactors and irradiated material is not quantitatively measured; for the material that can be measured, IAEA inspectors generally take sample nondestructive assay measurements. U.S. officials advised us that surveillance devices, such as TV monitors and cameras, are seldom used at research facilities fueled with HEU because the nature of the facilities does not lend itself to such devices. However, they noted that IAEA uses seals on HEU, but does not rely solely or indefinitely on them.

Substantial efforts have been made by member nations, particularly the United States, to develop new equipment. However, much of the equipment is considered to be in the prototype stage or under evaluation and testing. For example, only 11 out of the 21 new types of equipment developed by the United States over the last 5 years is in routine field use by IAEA inspectors.

IAEA estimates that the cost of this new safeguards equipment through 1985 will be about $20 million with an additional $10 million for maintenance and consumable supplies (e.g., seals and film). [2] With inflation, IAEA officials believe the total cost for equipment, maintenance, and supplies would be about $40 million through 1985. ACDA pointed out that most of this amount would be used for safeguarding facilities which do not handle HEU. Even without additional costs, many member nations have already expressed concern about the rising cost of safeguards.

It is generally recognized that new procedures and techniques must also be developed to meet the safeguard challenges presented by the larger and more complex facilities that have come under safeguards in recent years. Large amounts of material in various forms are present in or flow through "bulk handling" facilities. For example, significant amounts of direct use material (e.g., HEU) at fuel fabrication facilities and enrichment plants, where HEU can be manufactured, have been cited as posing substantial problems for IAEA inspectors.

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[1] See our classified report entitled "International Nuclear Safeguards Need Further Improvement" (C-ID-81-4, Feb. 13, 1981).

[2] According to IAEA budget projections for 1982, it will spend about $2.1 million on safeguards equipment.

The task of safeguarding research reactors using HEU, on the other hand, has been characterized by one U.S. official as relatively straightforward--accounting for modest and discrete amounts of fuel. However, according to ACDA, IAEA has been responsible for safeguarding HEU at such facilities for more than two decades, but procedures and techniques for inspecting such facilities have not been standardized to the extent desirable. ACDA pointed out that although further development and standardization are needed, the large number of different types and sizes of research reactors limits how much standardization is possible. A DOE official advised us that DOE expected IAEA to request U.S. assistance in 1982 to develop an inspection methodology for large research reactors which use HEU.

NEED FOR FINANCIAL AND POLITICAL SUPPORT

Effective safeguards depend in large measure on the cooperation and support provided by member nations. For example, IAEA needs financial and political support which, in some cases, it has had difficulty obtaining.

Applying safeguards is only one of IAEA's functions. [1] About 24 percent of IAEA's total resources are expected to be used for safeguards in 1982. Member nations generally view IAEA safeguards as necessary but many maintain that the financial resources of IAEA should be used primarily for technical assistance to less developed countries and for the promotion of the peaceful uses of nuclear energy.

For several years, the United States has had a special support program to provide technical resources, funds and other support to IAEA when the budget channels of IAEA were not able to respond fast enough to meet IAEA-identified urgent safeguards needs. Under this program, the United States has provided, through 1981, $23 million in assistance in the forms of (1) forty experts to complement IAEA's staff for 1 to 2 years, (2) the development of 21 different types of new safeguards equipment, (3) system studies, (4) training for inspectors, and (5) the development of safeguards techniques, procedures and equipment evaluation. A few other countries have also established special support programs to supply cost-free experts and develop new equipment for IAEA.

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[1] IAEA was created in 1957 to accelerate and enlarge the contribution of nuclear energy to peace, health, and prosperity throughout the world without furthering any military purpose.

The IAEA Statute provides that IAEA's expenses, including the costs of safeguarding nuclear material, are to be apportioned among all member nations. Our review showed, however, that although the cost of safeguards has increased substantially in recent years, the current IAEA financing formula insulates the majority of member nations from such increases. In 1982, 80 of IAEA's 110 members will provide less than 2 percent (about $424,000) of the safeguards budget. The same 80 countries will provide nearly 8 percent (about $4 million) of the non-safeguards budget. For 1982, 31 members are being assessed about $750 for safeguards--the same as the lowest assessment made in 1971. The following chart helps to illustrate the effects of IAEA's complex financing formula.

Examples of assessed shares for IAEA 1982 regular budget

	Safeguards portion	Non-safeguards portion
Argentina	$ 29,519	$ 408,675
Costa Rica	754	10,346
Ecuador	754	10,346
India	42,563	315,559
South Africa	17,849	222,443
United States	7,033,069	12,932,750

Political obstacles include rejection of whole categories of inspectors. Although every nation has the right to accept or reject a proposed inspector, many countries, including the United States, increasingly reject broad ranges of proposed inspectors on political, linguistic, or nationalistic grounds. The State Department contends that, in practice, the designation of inspectors has not been a serious problem and has not prevented inspections in any country or facility. However, according to IAEA officials, the practice is growing and has diminished safeguards credibility. They indicated that it has led to

--retaliatory discrimination by member nations,

--distortions in the recruiting pattern, forcing IAEA to accept a bias toward designating inspectors from within certain groups of countries, and

--ineffective deployment of inspectors in the field, and less-than-full utilization of inspectors specializing in particular types of facilities.

Continued support to improve safeguards seems appropriate. The cost of safeguards is low compared to the costs of world insecurity and increased military weaponry. However, care must be exercised so that IAEA does not become too dependent on the United States and a few other nations for its support. To retain its character as an international organization, IAEA must receive broader technical, political, and financial support from its members.

EXECUTIVE BRANCH RESPONSE TO OUR PREVIOUS REPORTS

U.S. officials generally agree that the effectiveness of international safeguards has been adversely affected by the problems IAEA has been experiencing and that member nations need to provide greater support to improve safeguards. However, some U.S. officials believe that while a few nations provide support to safeguards, many others either may not be able to help or, in fact, may want to diminish the function of international safeguards.

In previous reports [1] we recommended that the Secretary of State meet with other world leaders and IAEA officials to discuss the problems impeding the effective application of international safeguards and to develop a multinational plan to overcome these problems. We stressed the need for renewed consideration of how international safeguards should be financed, staffed, and otherwise supported.

The State Department commented that U.S. officials' promotion of continuing attention to these matters in IAEA and other appropriate international forums obviates the requirement for any formal multinational plan. The Department added that an effort to develop or promote such a plan could well detract from the effectiveness of IAEA's safeguards activities and its continuing efforts for safeguards improvement. These activities and efforts were, in the State Department's view, already achieving results.

However, U.S. officials generally believe that the IAEA safeguards system needs substantial improvement. Recently, the State Department concedes that actual in-the-field application of safeguards, although improving, is uneven and often falls short of what should, in principle, be done. Nevertheless, in December 1981 the Under Secretary of State for Management advised a congressional committee that the executive branch planned no new initiatives to help upgrade IAEA safeguards, but rather would continue existing programs. Moreover, the executive branch has proposed to defer payment of most of its fiscal year 1983 IAEA assessment to fiscal year 1984.

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[1] See our report entitled, "The Nuclear Non-Proliferation Act of 1978 Should Be Selectively Modified" (OCG-81-2, May 21, 1981) and our classified report entitled, "International Nuclear Safeguards Need Further Improvement" (C-ID-81-4, Feb. 13, 1981).

No new forum needs to be established to improve IAEA safeguards. We continue to believe, however, that the United States must work more closely with many member nations in order to develop an approach for providing adequate staffing and financial and technical resources to help IAEA fulfill its substantial safeguards responsibilities.

AGENCY COMMENTS AND OUR ANALYSIS

ACDA agreed with our general thrust that IAEA needs increased resources for inspecting HEU and that IAEA is encountering certain difficulties in applying its safeguards to HEU.

The State Department commented that, except for two large critical assemblies, the HEU safeguarding task for IAEA is fairly straightforward and State has no reason to believe that IAEA is not doing an adequate job. DOE, in its comments, emphasized that [illegible] inspections and related safeguards measures can provide reasonable assurances that no HEU has been diverted from a research reactor.

DOE also commented that IAEA is acting prudently in giving its priority safeguards attention to bulk handling facilities such as reprocessing plants or HEU fabrication plants, rather than "squandering" its resources on minor research reactors. IAEA's attention obviously has to be devoted to those cases or situations involving the greatest quantities or production of weapons-usable materials, and DOE believes it would be a misallocation of IAEA resources to shift substantial resources to research reactors possessing less than one significant quantity of material. DOE added that IAEA has reported continual progress in upgrading its safeguards procedures at research reactors.

ACDA in commenting to DOE on the need to continue the reduced enrichment program stated, in October 1981, that the conversion of research reactors from HEU to non-weapons usable LEU would:

--reduce safeguards problems and

--diminish the consequences of a nation's abrogating its safeguards obligations as well as essentially eliminate the risks of nuclear terrorism associated with the current widespread use of HEU.

We agree that as long as the shortage of inspectors exists, IAEA will have to concentrate its efforts on certain important facilities and will not be able to inspect all facilities subject to safeguards. However, we believe the quality of assurances that IAEA safeguards can provide has been adversely affected to the extent that IAEA only carried out 50 percent of its estimated routine inspection effort.

CHAPTER 5

U.S. TRACKING SYSTEM IS WEAK IN PROVIDING INFORMATION ON U.S.-SUPPLIED HEU

DOE has a central computerized system to track all nuclear exports, including HEU. However, our review of this system showed a number of weaknesses:

--Information within the system is often incomplete or inaccurate. A 2-year effort to correct the data is nearly completed but readily available information has not been used to verify and reconcile the data in the tracking system.

--Intended users of the system find it inadequate to meet their needs.

--Although this one DOE system is supposed to provide a central repository for storage and retrieval of information needed to track HEU furnished to other countries, DOE and NRC have developed three other information systems on HEU supplied abroad.

The need to have four separate U.S. systems gathering data on HEU supplied abroad appears questionable. 1/ Considering the costs of the systems and the needs of the users, efforts to streamline and consolidate needed information into one system seem to be warranted. We believe that to be responsive to its intended users, an international nuclear tracking system should provide accurate, up-to-date information in a useful format.

TRACKING SYSTEM CONTAINS UNRELIABLE DATA DESPITE UPDATE EFFORT

The DOE computerized tracking system, implemented in 1968, is called the Nuclear Materials Management and Safeguards System (NMMSS) and contains data on 19 different nuclear materials, including HEU, which have been supplied by the United States both domestically and abroad. In 1977, DOE established a subsystem to NMMSS which contains only international nuclear material information--the International Nuclear Materials Tracking System, NMMSS/INMTS. According to DOE, the mission of INMTS is to record and maintain export, import, and retransfer data for U.S.-origin material.

1/Although not evaluated in this report, it should be noted that IAEA maintains a computerized information system on nuclear material, including HEU, under IAEA safeguards.

Our review showed that the NMMSS/INMTS system is not reliable for tracking HEU supplied overseas for the following reasons:

- --Information on HEU exports between 1954 and 1968 was manually recorded and is generally considered incomplete.
- --The system shows where the material was originally shipped, but may not identify current location of the exported HEU. Moreover, the system does not show the current physical status of the material (e.g., irradiated, fabricated, or reprocessed).
- --Information from the tracking system on the amount of spent HEU returned to the United States did not agree with records at the Federal facilities that actually received the material.
- --In trying to upgrade the system, DOE may have been overlooking sources of data which would be useful in verifying/reconciling the amounts shown in the system.

Pre-1968 manual system

In establishing the beginning inventory base for the computerized system, exports prior to 1968 were compiled only as a total figure summarized from manual reports rather than being entered as individual transactions. As part of its upgrade effort, DOE has been working to reconstruct these early export transactions for input into the computerized system. This task is difficult because (1) many documents during that time were maintained as loose pieces of paper containing little information about the transaction, and (2) some documents are missing. DOE officials recognize that these problems create some gaps that will continue to exist in the computerized data base despite the upgrade effort.

System may not identify location or current status

The NMMSS/INMTS international tracking system can provide data on the country and facility to which nuclear exports were initially shipped, certain overseas retransfers of U.S.-supplied nuclear material, and material returned to the United States. Agreements for cooperation do not require prior approval of the United States or subsequent notification to the United States of movements of U.S.-supplied nuclear material within a country, or in the case of EURATOM, within the community of EURATOM nations. Thus, the tracking system cannot assure the current facility location or, in the European Community, even the country location of U.S.-supplied material.

Additionally, information in the international tracking system does not show the current state of the nuclear material exported, i.e., whether it is unirradiated, irradiated, fabricated, burned-up, or reprocessed. When DOE's nuclear material leasing program was in effect (from 1955 to 1974), burn-up information was routinely provided to the United States and and was incorporated into the central system. Although burn-up information is available through other Government systems, adjustments are not being made in NMMSS/INMTS to reflect it. According to an Argonne National Laboratory official, the average burn-up could be as high as 50 percent over the useful life of the fuel.

Although the NMMSS/INMTS system shows HEU supplied to specific facilities, DOE said that this system is not designed to track the movement of U.S.-origin materials within a cooperating nation (or within EURATOM) or the status of the material. DOE added that if the United States moved in that direction, the United States would have to impose an entire series of new reporting requirements on cooperating countries which could be resented by most of them. Also, DOE contends such a requirement is not easily justifiable since all U.S. exports are already subject to IAEA or EURATOM accountability and verification. The United States, DOE commented, looks to these bodies to perform the basic safeguards functions to help determine that no diversions occur.

DOE officials argue that agreements for cooperation do not require the collection of data on fuel fabrication, certain material movements, burn-up, reprocessing losses, and inventories. A State Department official told us, however, that nothing in the agreements either authorizes or precludes collecting this information. DOE officials advised us that collecting data on the physical state of HEU is not routinely done for the centralized computer system because the United States requires this data only if the exported material is retransferred to another foreign agreement entity or is returned to the United States. However, we learned that consent of the United States for reprocessing or otherwise altering transferred material (including HEU) is explicitly required by agreements for cooperation, as well as U.S. export licensing criteria. (The only exception involves EURATOM.) Thus, information on some changes in the physical status of U.S.-supplied HEU should be routinely available from DOE records.

Moreover, the United States requires that each foreign facility operator requesting exports of 5 kilograms or more of HEU submit detailed inventory information on the facility's stocks of U.S.-supplied HEU on hand and data on the current and planned use of the facility which is to receive the material. We believe such information is readily available and could be routinely reconciled with the information in the international tracking system. In addition, DOE pointed out that in newer agreements for cooperation, the cooperating nation authorizes IAEA to provide the United States with inventory data.

Spent fuel return records did not agree

During our review we compared information on the amount of spent HEU fuel returned to the United States as contained in the NMMSS/INMTS system with similar information from U.S. facilities that actually receive spent HEU fuel. The comparison showed a number of discrepancies which, at the time, DOE officials were unable to explain.

While our draft report was with the agencies for review and comment, we asked officials at the Savannah River Plant and those responsible for the NMMSS/INMTS system at Oak Ridge to reexamine their data on spent HEU returns in light of the discrepancies we had noted. On April 23, 1982, the Savannah River Operations Office notified us that its staff had reviewed over 2,000 individual transactions and had identified the following types of differences.

--Inadvertent inclusion of materials other than HEU with the NMMSS/INMTS data on HEU.

--Transaction quantities inadvertently omitted from NMMSS/INMTS or Savannah River records.

--Quantities in the NMMSS system reflected the original shippers' estimated values not the more accurate Savannah River measured values.

--Some spent HEU fuel had been received by other facilities and not included in Savannah River records.

Savannah River officials advised us that they would be making some adjustments to their records and that their findings would be forwarded to Oak Ridge so that appropriate changes to reconcile the information could be made in the NMMSS/INMTS system.

Data verification has not been completed

In February 1980, DOE began a data verification effort to compare the data in the tracking system to other U.S. data sources in order to verify the accuracy of the NMMSS data base. A staff of eight people is in the process of verifying the computerized data with other records kept since 1954. The project is targeted for completion in September 1982. DOE officials believe that a thorough review of transaction documents, correspondence, licenses, contracts, and other pertinent records will enable them to correlace and refine the data now in the system.

Among the data which DOE has reviewed in this verification effort are

--contractual information on uranium enrichment contracts with foreign entities, and

--financial records on the sales and leases of nuclear materials by the Atomic Energy Commission.

Although much has been done to verify and locate missing NMMSS/INMTS data, DOE officials said they should also look to foreign governments to help reconcile the records of U.S.-supplied nuclear material shipped abroad. To date, DOE has completely reconciled its records with Australia and has initiated contacts with one other country as part of the requirements in the agreements for cooperation. A DOE official said that similar reconciliation efforts with other nations would take place only if adequate funding is provided.

Although DOE has taken a number of steps to improve the data in the NMMSS/INMTS system, it has not used the information obtained by the Argonne National Laboratory for its efforts to develop new LEU fuel for research reactors. DOE officials told us that they were reluctant to use such information to validate HEU data in NMMSS/INMTS because it was obtained from foreign reactor operators and dealt with current inventories and amounts licensed, not total amounts shipped, and/or because it lacked sufficient detail. 1/ There was no evidence of coordination between the Argonne system and the NMMSS/INMTS system. Officials in each program area indicated they had little knowledge about the other program. A DOE official associated with the Argonne system said he would readily coordinate with NMMSS/INMTS, but he had never been asked for any data. We believe that data from such a readily available source could be helpful in reconciling the information in the central tracking system and should be reviewed before any further attempt is made to obtain information from foreign entities.

1/The information in Argonne's system is used to analyze the technical justification for proposed HEU exports and contains information which should be useful in verifying NMMSS/INMTS records. (See pages 13 and 43.)

TRACKING SYSTEM CONSIDERED INADEQUATE TO MEET USER NEEDS

In recent years, DOE and NRC have received a growing number of requests for information relating to nuclear material from the Congress, the White House, the State Department, other U.S. Government entities, foreign governments, and private research organizations. However, many intended users have complained that DOE's centralized international tracking system has been unable to satisfactorily meet their needs. Officials at the Department of State, ACDA, and NRC have criticized the system.

Some officials said it is not being used in their reviews of export license applications because it contains inaccuracies, is not up-to-date and/or is incomplete, and the printouts are improperly designed for their needs. Some said they had come to rely on information from other sources. In addition, the system was criticized for the time lag required to respond to specifically designed reports, thereby reducing the usefulness of the system.

We requested and received from NMMSS/INMTS--after a time lag of 1 month--information on HEU supplied abroad and identified a number of anomalies which DOE officials were unable to explain. Among these were the following:

--The DOE international tracking system shows that the United States had supplied about 13,000 kilograms of contained HEU (element weight of exports less returns) to non-nuclear weapon nations from 1954 thru 1980. However, according to IAEA, it safeguards only about 11,000 kilograms of HEU in non-nuclear weapon nations from all sources. Because all U.S.-supplied material must be safeguarded and because the United States does not supply all of the world's HEU, the amount of IAEA safeguarded HEU should be greater than the amount supplied by the United States. DOE officials, however, were unable to explain the difference.

--The printout showed shipments to 246 accounts in non-nuclear weapon nations. IAEA safeguards 175 research reactors and a few HEU fuel fabricators. Because all facilities in non-nuclear weapon nations receiving U.S.-supplied HEU must be subject to IAEA safeguards, a basic assumption is that the numbers should be comparable. DOE officials said that an IAEA safeguarded facility might be assigned more than one NMMSS code number, but they could not identify any examples. They were also unable to report how many facilities were included in the 246 accounts.

--The computer printout contained a number of mathematically incorrect enrichment percentages which the officials could not explain.

--The printout contained many negative numbers which DOE officials said must represent some adjustments, yet they did not know why negative entries would be shown for the amount supplied abroad.

In an effort to improve the international tracking system and to determine the needs and perceptions of the users, DOE distributed approximately 150 questionnaires within DOE headquarters, field organizations, facility contractors, NRC, ACDA, and State. A frequently reported criticism was that reports from the system are insufficiently flexible. NRC noted in a separate criticism that, although material accounting data exists in the interational system, the lack of an integrated data base and the lack of direct access to the data limited the analyses that could be performed.

OTHER U.S. SYSTEMS GATHER HEU DATA

Although the NMMSS/INMTS system, located in Oak Ridge, Tennessee, 1/ is the official central repository for storage and retrieval of information needed to track HEU shipped abroad, it is not the only such information system maintained by the U.S. Government. DOE also maintains information on HEU supplied abroad as part of its Reduced Enrichment in Research and Test Reactors (RERTR) progr m and the Special Nuclear Materials Tracking and Management System (STAMAS) at its Argonne and Lawrence Livermore National Laboratories, respectively. 2/ NRC maintains its own computerized system with information on HEU supplied abroad--the International Programs Export/Import License Tracking System (IPELTS).

Operating costs for the four systems are projected to be nearly $1.4 million in fiscal year 1932. It is important to note that these are total costs for the systems, not only the costs for gathering and maintaining information on HEU.

1/NMMSS/INMTS is operated by the Union Carbide Corporation under contract to DOE.

2/Argonne National Laboratory is located near Chicago and Lawrence Livermore National Laboratory is near San Francisco.

Fiscal Year 1982 Budget Estimates for Information Systems Dealing With HEU (note a)

	($000 omitted)
NMMSS/INMTS	$ 525
STAMAS	b/905
RERTR	(c)
IPELTS	18
	$1,448

a/Except for RERTR, each system contains information on a number of nuclear materials, including HEU.

b/According to Lawrence Livermore National Laboratory, about $50,000 of the $905,000 is related to the disposition of HEU.

c/RERTR is a noncomputerized system. Its records are manually maintained and no cost breakdown is available for the information gathering segment.

As discussed in chapter 6, the RERTR program was begun in 1978. An integral part of the program is the accumulation and analysis of information on the current status of research reactors, including general operating data; the current inventory of HEU; spent fuel inventory; and HEU reprocessed. This information serves two purposes--it provides data for the economic and technical justification for an export license (see ch. 2), and determines the feasibility of converting research reactors to LEU fuel. (See ch. 6.)

Lawrence Livermore's STAMAS system is a computerized data system which was developed in 1977 to provide more accurate information on the amount, composition, and location of plutonium in the world. In 1981, STAMAS began developing a computer data base to describe the flow and stockpiles of HEU. Despite the fact that STAMAS and NMMSS/INMTS are both called tracking systems and contain information on HEU, a STAMAS official said the two share only the topical concern for fissile material flow but that the goals, operations, and outputs of the systems are different. One major difference is that NMMSS/INMTS does not focus on proliferation while STAMAS is a substantial component of DOE's efforts to technically analyze the nuclear proliferation threat by monitoring material which is not of U.S. origin or does not cross U.S. boundaries, as well as U.S.-supplied material. Officials from both programs said there has been very limited coordination and/or information exchange between these two DOE systems. Likewise, coordination between STAMAS and the RERTR program has been very limited even though both contain several similar data elements, including reactor name, location, inventory levels, and general operating data.

The IPELTS system was developed by NRC in 1977 as a computerized method of accumulating information on export licenses. The IPELTS system maintains individual license information such as the name of the applicant; material type with element and isotope weights; enrichment percentage; plant, facility and country; intermediate consignee; ultimate end use; and dates the license was issued and will expire. IPELTS does not record the actual supply or receipt of material, nor track nuclear material abroad. License information from IPELTS is provided to NMMSS/INMTS. In this regard, IPELTS supplements the central international tracking system.

Thus, four separate systems are maintaining information on HEU supplied abroad for different but closely related reasons. The NMMSS/INMTS system tracks HEU actually exported; IPELTS provides information on the amount of HEU licensed for export; the RERTR system gathers data on the current inventory of HEU at foreign facilities; and STAMAS is developing data on international flows of HEU. It can be argued that each system complements the others and each concentrates on a different aspect. However, the need to maintain four separate systems to monitor or track certain aspects of HEU supplied abroad appears questionable. None of the systems, by itself, affords U.S. officials the capability to quickly and coherently see the complete picture.

CONCLUSIONS

The central computerized system to track HEU supplied abroad (NMMSS/INMTS) is incomplete and inaccurate. Intended users also consider it inadequate and unreliable. DOE officials have been working to improve the information in the system, but have not used some readily available information within their own Department to help verify the quantities of HEU supplied abroad.

Furthermore, the U.S. Government is currently maintaining four distinct systems to gather information on HEU supplied to foreign countries--DOE has three systems (NMMSS/INMTS, STAMAS, and RERTR), NRC has one (IPELTS). Individually, however, each system provides only a segment of information (e.g., amounts exported, amounts licensed for export, or amounts currently on hand at the foreign facility). We believe reconciliation and efforts to consolidate the information into a more accurate and comprehensive system are warranted.

RECOMMENDATIONS TO THE SECRETARY OF ENERGY

We recommend that the Secretary of Energy, in conjunction with the Chairman of the Nuclear Regulatory Commission, streamline and consolidate the information maintained on HEU supplied abroad into a more accurate, comprehensive, and flexible system, which meets the needs of the intended users, in the most economical and efficient manner.

To increase the accuracy and utility of such a system, the Secretary of Energy should direct that information from other readily available sources be used to verify and reconcile the data on HEU exports within the system.

AGENCY COMMENTS

DOE commented that, in accordance with our recommendation, it is initiating a review to see whether a better integration of the different systems can be achieved even though they are designed to serve different purposes. NRC said that it agreed with the recommendation that information on U.S.-supplied nuclear material should be streamlined and consolidated, but it was not clear to NRC that this could be best accomplished through the development of a single information system.

NRC emphasized that no U.S. Government agency currently has been assigned responsibility to track U.S.-origin nuclear material within foreign entities and negotiation of international agreements with export recipients would be required to accomplish this. NRC added that sources have not been developed for collecting transaction data for individual foreign facilities or for transfers between countries in EURATOM. However, DOE pointed out that in newer agreements for cooperation, the cooperating nation authorizes IAEA to provide the United States with inventory data.

Concerning the individual information systems, we received the following comments.

--DOE commented that INMTS was conceived in 1977 to automate a manual system of records dating from 1954 pertaining to the international transfer of U.S.-origin nuclear materials. The automation was completed in 1978, and a subsequent audit was performed to determine the accuracy and completeness of the data base. The data base was found to have serious problems and a "verification" project was planned to compare the data base with all pertinent available sources of data in the United States and correct the deficiencies to the extent possible. This project will be completed in 1982, and DOE believes the INMTS will then be able to perform, with an acceptable degree of accuracy, those functions it has been delegated.

--The Lawrence Livermore National Laboratory advised us that the STAMAS system does not yet monitor the flow and stockpiles of HEU abroad. The Laboratory described its efforts regarding HEU as being in an embryonic stage with the present focus on obtaining and understanding the data that might be obtained on the operating histories of the most interesting (from a proliferation viewpoint) research reactors. The Laboratory added that about $50,000 of its fiscal year 1982 budget has gone into this evaluation of operating histories and the associated questions of HEU disposition.

DOE commented that discussions have been initiated with the Lawrence Livermore National Laboratory on the desirability and feasibility of addressing research facilities and materials such as HEU under the STAMAS effort. DOE indicated that should HEU data be monitored by STAMAS, this system would use NMMSS/INMTS data as a portion of its input. Nevertheless, DOE emphasized that although STAMAS does address "tracking," it is not an accountability system and cannot provide accountability data.

CHAPTER 6

U.S. EFFORTS TO REDUCE

LEVELS OF WEAPONS-GRADE URANIUM ABROAD

Much of the U.S. non-proliferation policy is centered around minimizing the use of HEU. The reduced enrichment program is one of the few concrete U.S. non-proliferation initiatives to gain widespread international support.

Our review showed that progress has been made in developing new LEU fuels and in obtaining foreign support for the program. However, the reduced enrichment program has experienced several limitations which have been hampering completion of the conversion effort. These include financial constraints on the U.S. Government program; the limited market potential to interest U.S. private sector involvement without continued Government support; and various foreign concerns about such issues as the lack of participation by U.S. reactor operators, potential difficulties in getting converted reactors (e.g., using new fuel) relicensed, technical problems associated with reprocessing and waste disposal, and uncertainty of U.S. willingness to continue accepting spent U.S.-origin fuel from foreign research reactors if they convert to the new fuel.

In addition, two U.S. initiatives announced at the 1978 United Nations Special Session on Disarmament were aimed at limiting the spread of HEU exported around the world. We learned during our review, however, that the United States has done little, to date, to carry out these proposals.

We believe that reducing the use of HEU is a sound non-proliferation objective, but further efforts are needed if the conversion to LEU fuels is to become a reality in the next few years.

THE REDUCED ENRICHMENT PROGRAM

In April 1977, the Carter administration adopted a new policy aimed at minimizing the use and distribution of HEU. As a result, in 1978 DOE launched the RERTR program as a multi-year program to provide the technical means to convert research reactors now using uranium enriched to 90-percent or more U-235, to 20-percent U-235 fuel or, where necessary, 45-percent U-235 fuel. The program structure was developed to accommodate the large number of reactors involved (approximately 156 worldwide which use U.S.-origin uranium enriched to more than 70-percent U-235), their design diversity, their different fuel types, and the various requirements of the more than 35 countries in which they are located.

The RERTR program has both short-term and long-term goals. The short-term goals are to develop and demonstrate the technology for medium enriched uranium (45 percent) and LEU (less than 20 percent) fuels, using current fuel fabrication techniques, which can then be used by most research reactors. The long-term goals are the development, testing, and commercialization of the new fuels, one of which the executive branch believes could be used in all but 3 or 4 research reactors. The State Department commented that full-scale testing of LEU fuels has not yet advanced to a stage where conversion of either foreign or domestic reactors to such fuel is presently feasible--several years of further DOE test work on fuels are needed. According to U.S. officials, the best estimates for converting all of these reactors are as early as 1986 and as late as 1988.

U.S. officials told us that progress is continually being made, primarily through DOE's research and development activities. They cite the following examples:

--Major emphasis has been placed on encouraging and assisting all research reactor fuel manufacturers, both in the United States and abroad, to develop and apply the technology necessary to be able to manufacture reduced enriched uranium. As a result, fuel manufacturers have made substantial efforts in the development and application of that technology.

--To expedite testing of proposed reduced-enriched uranium fuels as they become available from manufacturers, the U.S. Government is providing accelerated irradiation services in the Oak Ridge Research Reactor.

--Joint studies by Argonne National Laboratory and foreign reactor operators are designed to (1) define acceptable fuel element designs using appropriate LEU material, (2) convince the operators of the potential performance and safety of the relevant fuel in their respective reactors, and (3) provide the bases for establishing conversion schedules. Joint reactor-specific studies are in progress for 23 reactors from 14 countries.

--Tacit understanding has been obtained from foreign reactor operators that conversion from HEU to LEU would take place when the appropriate fuels, currently under demonstration, are adequately tested to satisfy licensing requirements within their country.

Apart from, but in consort with, the RERTR program, one U.S. company developed an LEU fuel (referred to as Triga fuel) for its own type of research reactor. However, this particular fuel is not readily usable in research reactors built by other companies which comprise the majority of research reactors worldwide.

LIMITATIONS AFFECT IMPLEMENTATION OF THE REDUCED ENRICHMENT EFFORT

Notwithstanding the progress the RERTR program has made, several factors are hindering the implementation of the reduced enrichment effort. Consequently, many countries have taken a wait-and-see attitude about actual conversion to the new fuels. To date, only one research reactor has been converted through the RERTR program. The Ford Nuclear Reactor in Michigan has been converted and licensed by NRC to use one of the new LEU fuels for "full-core demonstration" purposes.

U.S. funding constraints

According to DOE officials, the most significant problem hindering the RERTR program has been lack of adequate funding. One program official indicated that the program's funding under DOE's authority has fluctuated.

Fiscal year	Funding level (million)
1978	$ .64
1979	3.85
1980	4.95
1981 (note a)	2.56
1982 (estimated)	4.14
1983 (requested by ACDA) (note b)	4.80

a/In fiscal year 1981, only $1 million was specifically authorized for RERTR. Additional funding of approximately $1.6 million was provided from other programs by the Department of State, DOE, and ACDA.

b/In fiscal year 1983, DOE requested no funds for RERTR.

According to the fiscal year 1983 ACDA budget submission, ACDA would assume financial responsibility for the program. RERTR program officials had anticipated that RERTR would be funded outside DOE. These program officials had hoped the funding would come from the State Department or ACDA, either of which, one official felt, would give the program a higher priority than DOE had given it. DOE has taken the position that by the end of fiscal year 1982, 90 percent of the RERTR research and development effort will have been completed. DOE officials said that the next steps--commercialization and deployment of the fuel--are not DOE projects. ACDA commented that, in its opinion, the RERTR research and development will not be 90-percent completed by the end of fiscal year 1982. ACDA added that considerably more research and development efforts are needed.

Several U.S. officials said they believed that if a lack of adequate funding for the U.S. RERTR program occurred, it would, in turn, adversely affect foreign participation in the overall effort to reduce HEU use. This belief was substantiated by one Japanese official who said that without the United States, it was uncertain whether Japan would continue its LEU effort. On the other hand, West German and French officials told us that their conversion programs were independent of the U.S. program and that their countries would probably continue regardless of the future status of the U.S. program. A program official commented that West German and French commercial fuel fabricators of research reactor fuel have made similar statements.

Market limitations

Officials at U.S. companies indicated that, although their companies have the technical capabilities to produce LEU fuels, it is questionable whether they would get into the market without U.S. Government support. They indicated the limited market potential for these fuels poses a significant risk. Furthermore, because of a lack of interest by U.S. vendors in providing fabrication services for the fuel to be used in the RERTR tests, the United States has relied on France and West Germany for such services. According to DOE, there is only one U.S. firm interested in commercially fabricating the new fuels developed under the RERTR program. Officials at that company said they probably would not do the conversion work without Government support because the cost would be too high.

Foreign perceptions and concerns

A number of issues complicate the acceptance of the new LEU fuel by foreign reactor operators. Frequently foreign operators perceive that a double standard may be applied in deciding the acceptability of using HEU in foreign and U.S. research reactors. For example, the U.S. Government has not indicated whether it will restrict or inhibit the continued use of HEU in U.S. reactors. According to an Argonne National Laboratory official, there have been only limited discussions between U.S. operators and DOE about switching to LEU. The lack of participation by U.S. facilities in converting to the new LEU fuel could undermine foreign acceptance of the new fuel and, thus, negate an important part of the U.S. non-proliferation objective. Of the 156 research reactors worldwide which use U.S.-supplied HEU enriched to between 70 and 94 percent in U-235, 54 (about one-third) are located in the United States.

The State Department commented that, although the use of LEU by U.S. research reactor operators is primarily a domestic policy issue, (1) a consistent approach between domestic and foreign policies would benefit overall non-proliferation goals and (2) recent proposed changes in NRC safeguards requirements would provide an incentive to NRC licensed U.S. research reactor operators to convert to LEU, when it becomes available.

U.S. officials told us that the need to license the new fuels could slow HEU conversion abroad. According to the State Department, each country may have to relicense its facilities, some of which are 20 to 30 years old. Foreign research reactor operators believe that, in addition to limited modifications of their facilities to use the new LEU fuel, they would also have to significantly upgrade their facilities to meet new safety standards and current licensing criteria of their countries.

At the September 1981 IAEA Seminar for Research Reactor Operators, foreign operators voiced concern about the reprocessing of the new LEU fuel. In most countries, the license authority will not allow a reactor to operate unless it can prove that the fuel can be reprocessed or that a safe waste disposal can be ensured.

Because there is no U.S. policy on receiving spent LEU fuel from abroad, countries are concerned as to whether or not the United States, when this fuel is available, will accept it back when it is spent. According to French operators, once the United States guarantees that it will accept this spent LEU fuel, it is conceivable that HEU conversion would become more attractive to research reactor operators. The United States currently does accept spent U.S.-origin HEU fuel from foreign research and test reactors, but generally, not spent slightly enriched fuel from power reactors. (This issue is discussed in ch. 2 under "subsequent arrangements.")

Also, reprocessing plants throughout the world may not be willing to accept the new fuel because significant modifications to the facilities may be required. The relatively small amounts of such fuel, as compared to the larger amounts of other spent fuel normally reprocessed, could make such modifications economically impractical.

IMPLEMENTATION OF INITIATIVES ANNOUNCED AT U.N. HAS BEEN LIMITED

At the 1978 United Nations Special Session on Disarmament (UNSSOD), the U.S. Ambassador announced two initiatives designed to minimize the use of HEU. They were:

--Authorizing $5 million over 5 years to provide 20 percent enriched uranium fuel for research reactors through IAEA, with preference to developing countries party to the NPT.

--Providing up to $1 million annually in fuel cycle services to assist countries in the use of LEU fuel in research reactors. (This program was not linked to NPT adherence.)

The United States, however, has done little, as yet, to carry out these proposals. According to a State Department official, the initiatives are being implemented, at least to some extent. U.S. financial support for the two initiatives has been as follows:

1979	--$75,000 to IAEA to study the feasibility of using 20 percent enriched uranium fuel in research reactors.
1980	--$435,000 to Argonne National Laboratory's RERTR program for training reactor operators and for defraying costs of assistance for reactor conversions in IAEA selected developing countries.
	--$75,000 to IAEA for the 20 percent enriched fuel program.
	--$50,000 to Malaysia for fuel fabrication costs associated with the purchase of LEU (Triga) fuel for one of its research reactors.

Money to address these initiatives has come from the Foreign Assistance Act--U.S. voluntary contributions. A State Department official informed us that he has requested funding over and above the normal U.S. voluntary contribution each year; but, to date, has not received any additional funding for the UNSSOD initiatives. For example, for fiscal year 1982, State requested $18.5 million for voluntary contributions, of which $4 million was designated for the UNSSOD initiatives. However, the Office of Management and Budget cut the request to $14.1 million by eliminating funding for those initiatives.

It can be argued that the RERTR program addresses the same overall objective of the U.S. initiatives announced at UNSSOD, i.e., minimizing the use of HEU abroad. However, according to U.S. Government officials, the RERTR program was never intended to meet the UNSSOD initiatives.

Nevertheless, the 20 percent enriched fuel is not yet available for routine use and the United States has not yet fulfilled the initiatives announced at the UNSSOD.

CONVERSION PROGRAMS IN OTHER COUNTRIES

Several other countries have also initiated programs in the areas of reduced enrichment fuels for research and test reactors.

In 1975, France started a general program of fuel development and reactor study. The development of the so-called "Caramel" fuel is a result of the program. Caramel fuel is a low enriched fuel containing 7 percent U-235 and, according to the French, is able to fulfill principal reactor requirements of fuel cycle length and performance. To date, only one French research reactor has been converted to Caramel fuel.

According to DOE, West Germany is implementing a 5-year, $30 million Deutschmarks (about $12 million) program on enrichment reduction in research reactors. The main objective is to develop and test fuel and fuel elements essential for converting reactors to LEU fuels. West Germany also offers consulting services to organizations considering enrichment reduction of their research reactors.

Japan has a 5-year program for the conversion to reduced enrichment uranium fuel. The Japan Atomic Energy Research Institute and the Kyoto University Research Reactor Institute research reactors are being used in this program. Japan is using a step-by-step approach to demonstrate the engineering feasibility of medium enriched uranium fuels to satisfy requirements made by its government for changing fuel designs. Full core demonstrations of alternative fuels in both institutes' reactors are expected by mid-1983.

Canada, Argentina, Denmark, the United Kingdom, Spain, and the Soviet Union also have programs dealing with LEU fuels.

A paper delivered by an Argonne Laboratory official at an international meeting in early 1981 described the international scene as one of "excellent agreement and cooperation" between the RERTR program and various foreign national and international organizations. Furthermore, he said that these organizations are conducting "ambitious programs" with the same general goals as the RERTR program.

CONCLUSIONS

Although the executive branch has taken steps to develop new LEU fuels for research reactors, it is difficult at this time to measure the effectiveness that this effort will have in converting research reactors to LEU fuels and in significantly reducing worldwide inventories of HEU. Most countries recognize the need to reduce the use of HEU worldwide, but have taken a wait-and-see attitude in the actual conversion of the research reactors because of a variety of concerns and uncertainties. According to DOE, many countries have deferred their conversion decisions pending demonstrations of the new fuels.

We believe that reducing the use of HEU abroad is a sound non-proliferation objective. However, a number of issues need to be resolved if the conversion to LEU fuels is to become a reality in the next few years.

AGENCY COMMENTS

The Department of State and ACDA agreed that reducing the use of HEU is a sound non-proliferation objective.

DOE commented that it believes that substantially more work is needed to encourage nations to actually shift to lower enrichment. However, DOE stressed that the RERTR program is designed to develop the technology of LEU fuels to the point where they can be put to practical application with the assent of foreign and domestic reactor operators--including foreign licensing and regulatory authorities. DOE added that actual deployment of such fuels to foreign reactor operators is not within its control.

According to ACDA, the issues identified in this report which require resolution before foreign reactors actually convert to LEU are precisely those which the executive branch is giving high priority to resolving. ACDA cited the following examples.

--ACDA, along with some other executive branch agencies, has diligently supported funding the RERTR program in the fiscal year 1983 budget at the level necessary to complete the program as expeditiously as possible.

--The technical and political problems associated with accepting and reprocessing spent LEU research reactor fuel are being addressed, and resolution of these problems is expected within the next year or so.

--Personnel in the RERTR program and executive branch are working with foreign governments and reactor operators to address the technical and licensing problems which must be solved before reactors are actually converted; and a spirit of international cooperation and optimism toward accomplishing the program's objectives continues to be demonstrated at international meetings of program participants.

--RERTR program personnel are working closely with a U.S. fuel vendor to transfer advanced fuel fabricating technology, which could make a U.S. vendor a competitor for research reactor fuel orders.

GARY HART
COLORADO

COMMITTEES:
ARMED SERVICES
ENVIRONMENT AND PUBLIC WORKS
BUDGET

United States Senate
WASHINGTON, D.C. 20510

July 14, 1981

Mr. Milton J. Socolar
Acting Comptroller General
United States General Accounting Office
441 G Street, N.W.
Room 7000 A
Washington, D.C. 20548

Dear Mr. Socolar:

Increasing concern over the proliferation of nuclear weapons has raised questions about the United States' ability to account for, and monitor the use of the highly-enriched uranium fuel it exports to foreign countries. For example, Victor Gilinksy, Commissioner of the Nuclear Regulatory Commission, has been quoted as saying, "To my knowledge, nobody keeps track of this material in a serious way."

In light of these questions, I request the General Accounting Office to undertake an investigation that will:

(1) Evaluate the mechanisms established in international agreements of cooperation for controlling the use of U.S.-supplied highly-enriched uranium (HEU) fuel and assuring adequate protection of HEU fuel shipments from terrorists.

(2) Assess the ability of the International Atomic Energy Agency (IAEA) to detect diversions of HEU and fissionable materials produced from this fuel, through use of material accounting techniques and of containment and surveillance devices.

(3) Ascertain the rationale for supplying HEU fuel to foreign countries and the possible nuclear proliferation consequences.

(4) Review the implementation and effects of the United States' programs announced at the United Nations Special Session on Disarmament in 1978 aimed at limiting the use of HEU fuel in research reactors, as well as any United States foreign policy initiatives in this area.

(5) Assess the system used by the United States for keeping track of its exports of HEU fuel and any fissionable materials produced from this fuel.

(6) Determine what controls, if any, the United States has over the use of fissionable materials produced from U.S.-supplied HEU fuel or in U.S.-supplied nuclear facilities.

My staff has discussed the issues presented in this request with Joseph F. Murray, group director for arms control and nonproliferation, International Division. If you have any questions about the scope or nature of this request, please contact me or my staff.

Thank you for your prompt attention to this matter.

Sincerely,

Gary Hart

Gary Hart

U.S. SHIPMENTS OF HEU SINCE 1954

Country	Quantity shipped (kilograms of isotope U-235)
Argentina	59.2
Australia	9.1
Austria	7.5
Bangladesh	(a)
Belgium	148.8
Bolivia	(a)
Brazil	7.1
Canada	1,392.6
Colombia	2.8
Czechoslovakia	(a)
Denmark	23.5
Finland	.8
France	4,550.1
Germany, West	6,206.6
Greece	6.1
India	(a)
Indonesia	2.4
Iran	5.2
Ireland	(a)
Israel	17.0
Italy	344.4
Japan	1,021.9
Korea	18.3
Mexico	5.7
The Netherlands	73.0
Norway	(a)
Pakistan	5.2
Philippines	3.0
Portugal	7.1
Romania	36.6
South Africa	30.2
Spain	12.3
Sweden	133.3
Switzerland	7.9
Taiwan	9.2
Thailand	4.8
Turkey	4.8
United Kingdom	2,140.7
Uruguay	(a)
Venezuela	(a)
Vietnam, South	(a)
Yugoslavia	5.2
Zaire	.3
Total	16,302.7

a/The cumulative quantity shipped is less than .05 kilograms

Source: Department of Energy reports from Nuclear Materials Management and Safeguards System, June and October 1981.

LIST OF PREVIOUS GAO REPORTS ON HIGHLY ENRICHED URANIUM AND RELATED ISSUES

Title	Date issued
The Nuclear Non-Proliferation Act of 1978 Should Be Selectively Modified (OCG-81-2)	May 21, 1981
International Nuclear Safeguards Need Further Improvement (C-ID-81-4) (Confidential)	February 13, 1981
Evaluation of Selected Features of U.S. Nuclear Non-Proliferation Law and Policy (EMD-81-9)	November 18, 1980
Evaluation of U.S. Efforts to Promote the Nuclear Non-Proliferation Treaty (ID-80-41)	July 31, 1980
Nuclear Fuel Reprocessing and the Problems of Safeguarding Against the Spread of Nuclear Weapons (EMD-80-38)	March 18, 1980
United Nations Special Session On Disarmament: A Forum For International Participation (ID-79-27)	July 3, 1979
Federal Facilities For Storing Spent Nuclear Fuel--Are They Needed? (EMD-79-82)	June 27, 1979

SUMMARY OF CRITERIA FOR AGREEMENTS FOR COOPERATION

(1) The cooperating party guarantees that safeguards specified in the agreement must be maintained on (1) transferred nuclear materials and equipment, and (2) special nuclear material used in or produced through the use of transferred materials and equipment, so long as the material or equipment remains under its control. The obligation continues whether the agreement itself terminates or is suspended.

(2) As a condition of continued U.S. supply, in the case of non-nuclear weapon nations, the cooperating party must maintain IAEA safeguards on all nuclear materials in all of its peaceful nuclear activities.

(3) The cooperating party must guarantee that no transferred nuclear materials, equipment, or sensitive technology, and no special nuclear material produced through the use of such transfers, will be used for any nuclear explosive device, research and development on such devices, or any military use.

(4) The United States must have the right to require return of transferred material and equipment from a non-nuclear weapon nation that detonates a nuclear explosive device or abrogates an IAEA safeguards agreement.

(5) Transferred material, restricted data,1/ production or utilization facilities, or any special nuclear material produced through the use of such material or facilities must not be transferred from the control of the cooperating party without U.S. consent.

(6) The cooperating party must guarantee the maintenance of adequate physical security on transferred materials and special nuclear material used in or produced through the use of any transferred materials or production or utilization facilities.

(7) No transferred material, or material used in or produced through the use of transferred material or transferred production or utilization facilities, may be reprocessed, enriched, or otherwise altered without prior U.S. approval.

(8) The United States must approve in advance storage facilities for weapons-usable material that is transferred, recovered from transferred source or special nuclear material, or recovered from source or special nuclear material used in a transferred production or utilization facility.

(9) All of the above criteria must apply to any special nuclear material, production facility, or utilization facility produced or built by the cooperating party with transferred sensitive nuclear technology.2/

1/"Restricted data" is any data concerning (1) the design, manufacture, or utilization of atomic weapons, (2) special nuclear material production, or (3) the use of special nuclear material in energy production. Not included is data declassified or otherwise removed from this category. (See 42 U.S.C. 2014 (y).)

2/"Sensitive nuclear technology" is defined in section 4(a) (6) of the NNPA.

Source: "The Nuclear Non-Proliferation Act of 1978 Should Be Selectively Modified" (OCG-81-2, May 21, 1981).

STATUS OF U.S. AGREEMENTS FOR COOPERATION

Cooperating partner	Status of U.S. effort
Argentina	Discussions begun October 1978. Limited informal discussions since then. (note a)
Australia	Agreement renegotiated, in force January 1981.
Austria	Discussions held June 1978. Suspended. Referendum voted against nuclear power.
Bangladesh	Agreement completed; signed in Dacca, Congressional review needed.
Brazil	Discussions begun June 1978. Informal discussions since then. (note a)
Canada	Agreement amended, in force July 1980.
Colombia	Agreement completed. Congressional review completed. Colombian Parliamentary ratification needed.
Egypt	Agreement completed, in force December 1981.
EURATOM	Limited discussions begun November 1978.
Finland	Negotiations last held June 1980.
Greece	EURATOM member as of January 1981.
IAEA	Agreement amended, in force May 1980.

a/Discussions are limited to assurances needed to permit continued cooperation under the existing agreement in conformity with Title III's export licensing criteria.

Source: Department of State as of December 1981.

India	"Special problems" involved. Nuclear cooperation addressed "in the context of broader discussions."
Indonesia	Agreement renegotiated, in force December 1981.
Japan	Negotiations in progress.
Korea, South	Discussions begun September 1978 and are ongoing.
Morocco	Agreement completed and entered in force May 1981.
Norway	Negotiations completed. Draft initiated May 1979. Under Presidential review.
Peru	Agreement completed. Congressional review completed, Peruvian parliamentary ratification needed.
Philippines	Discussions held May 1978 and May 1979. Further discussions were deferred due to pending litigation on reactor exports.
Portugal	Discussions held September and October 1978; and late 1979-80; not currently active.
South Africa	"Special problems" involved. Nuclear cooperation addressed "in the context of broader discussions."
Spain	Discussions begun March 1978. Limited discussions have been held.
Sweden	Negotiations in progress.
Switzerland	Discussions held May 1979. Limited discussions held subsequently.
Taiwan	Discussions held during 1979 and 1980 (non-governmental).
Thailand	Discussions held October 1978 but no current plans for a Thai nuclear program.
Turkey	Discussions held and then deferred. Draft provided by the U.S. in October 1980. Current agreement expired.
Venezuela	Current agreement expired. State Department expects discussions to commence soon on renegotiation.

ATTACKS AND/OR PHYSICAL SECURITY BREACHES AT NUCLEAR FACILITIES FROM 1966-1979

Date	Installation	Incident or result
November 18, 1966	U.K.: Bradwell reactor in Essex	Theft of 20 uranium rods; reasons obscure.
May 4, 1969	USA: Illinois Institute of Technology Reactor	A pipe bomb found.
September 1970	USA: Point Beach Reactor Two Creeks, Wisconsin	Dynamite discovered.
March 1971	U.K.: Springfield fuel fabrication plant	5 uranium rods disappeared; stolen perhaps in transit or at the Wylfa reactor in Anglesey.
August 1971	USA: Vermont Yankee reactor	Intruder wounded a night watchman before escaping.
December 7, 1971	USA: Stanford University Linear Accelerator in Calif.	2 bombs caused heavy damage to electronic control equipment.
June 25, 1972	USA: New York University reactor	Building broken into; no damage except door panel broken for access.
March 15, 1973	USA: Oconee, South Carolina	Break-in at fuel storage building; no material taken.
March 25, 1973	Argentina: Atucha I Reactor	Overrun by 15 men who caused light damage with the possible motive of gaining publicity for their group.
February 22, 1974	USA: Nuclear survey tower in Montague, Massachusetts	Tower destroyed by unbolting stays. Perpetrator is known.
August 27, 1974	USA: Plymouth I Reactor in Massachusetts	Fire caused minor damage to reactor. Neither perpetrators nor their motives known.
September 4, 1974	USA: U.S. Nuclear Corp., Oak Ridge, Tenn.	Attempted fence breach.
February 23, 1975	USA: Nuclear Fuel Services Erwin, Tenn.	Fence breach; no theft.
May 3, 1975	France: Fessenheim Reactor near Strasbourg	Casing of reactor extensively damaged by two explosions. Responsibility claimed.

Date	Installation	Incident or result
May 27, 1975	USA: Zion Reactor in Illinois	Unknown assailants apparently fired two shots at security guards. No damage reported.
June 6, 1975	France: Framatone's main computer at Courbevoie	Explosion caused extensive damage to the input terminals at main computer at Courbevoie. Responsibility claimed.
June 1975	West Germany: Biblis reactor	An individual carried a Panzer-faust bazooka into the plant to present it to the Director as part of a security demonstration.
July 1975	USA: Brunswick reactor in North Carolina	Guards failed to check identification badges of personnel entering the plant.
July 1975	USA: Quad Cities reactor in Illinois	NRC inspector entered plant through an open uncontrolled gate.
July 2, 1975	USA: Kerr McGee Nuclear Corp., Oklahoma City	Attempted forced entry.
August 1, 1975	Canada: Pickering reactor in Ontario	A visitor entered the plant carrying a satchel; he was not checked at the gate or during his brief visit.
August 15, 1975	France: Monts d' Aree reactor at Brennelis	Two bombs damaged watercooling tank and radiotelephone room causing reactor to be closed. An anonymous call claimed act was a protest against construction of nuclear facilities in Brittany.
September 25, 1975	USA: Mass. Inst. of Tech.	Attempted forced entry.
January 27, 1976	USA: Three Mile Island Reactor in Pennsylvania	Intruder scaled security fence and entered protected area; he later drove off without being apprehended.
Nov.14-15, 1976	France: Fargnac Uranium Mines	Bombs caused damage to the extraction plant and other facilities. Responsible group believed known.

Date	Installation	Incident or result
July 1977	France: French Electric was object of terrorist acts.	On July 8, Paris residence of its Director General was attacked. Responsibility claimed. Days later, explosions occurred at two local offices, apparently the protest of a local group against area construction.
October 10, 1977	USA: Trojan Nuclear Power Plant in Rainier, Oregon	Explosive device detonated outside gates causing minor damage to a visitors center. Responsible group known.
Nov. 19-20, 1977	France: A series of ostensibly nuclear objectives	Group armed with machine guns and explosives struck objectives. On November 21, a group claimed responsibility. Declared objective—terminating nuclear energy development in France.
December 1977	Spain: Lemoniz Nuclear Power Plant	Four persons assaulted the facility. The guards repulsed them, killing one.
March 1, 1978	Spain: Iberduero utility properties	Incendiary bombs used by known group to destroy properties.
March 17, 1978	Spain: Lemoniz	Explosion caused deaths of 2 workmen and injuries to 14. Extensive facility damage.
April 1978	Spain: Lemoniz	Explosions destroyed four electricity pylons of constructor and damaged nearby electrical equipment.
May 31, 1978	Sweden: Goteborg	Municipal building and German church damaged by a bomb apparently placed by an antinuclear group.
February 19, 1979	Switzerland: Kaiseraugst Nuclear Power Plant in Basel; Liebstadt Nuclear Power Plant	Explosion severely damaged information center. Another caused minor damage to Liebstadt storage facility.
April 6, 1979	France: La Seyne-sur-Mer nuclear manufacturing plant	Explosions caused millions of dollars worth of damage, most significantly, to certain Iraqi reactor components. Responsible group anonymously identified.

Date	Installation	Incident or result
April 8, 1979	West Germany: Esensham Nuclear Power Plant at Bremenshaven	Two primitive explosive devices damaged a pylon supporting high tension power lines. Damage was not extensive and the line was not severed.
June 1979	Spain: Lemoniz	Three armed persons breached plant security, subdued three workmen, and placed an explosive device near a turbine. One workman died. A group claimed responsibility.
November 1979	Switzerland: Goesgen Nuclear Plant	Explosion did not damage reactor although it nearly ceased functioning. Blackouts resulted and transformer on the periphery of the plant was damaged.
November 1979	Spain: Maliano	Two explosions during the night severely damaged the nuclear equipment factory. Responsiblity claimed.

Source: Flood, M., "Nuclear Sabotage." Studies in Nuclear Terrorism, Norton and Greenberg (eds.). G. K. Hall and Co., Boston, Mass. 1979.

Pilat, J. F., "Ecological Politics: The Rise of the Green Movement." The Washington Papers, Vol. VIII. The Center for Strategic and International Studies; Georgetown University, Washington, D.C. 1980.

COUNTRIES WHICH HAVE SIGNED AND/OR RATIFIED THE CONVENTION ON THE PHYSICAL PROTECTION OF NUCLEAR MATERIALS AS OF FEBRUARY 1, 1982

State	Date of signing	Date of ratification
Austria	March 3, 1980	
Belgium	June 13, 1980 a/	
Brazil	May 15, 1981	
Bulgaria	June 23, 1981	
Canada	September 23, 1980	
Czechoslovakia	September 14, 1981	
Denmark	June 13, 1980 a/	
Dominican Republic	March 3, 1980	
East Germany	May 21, 1980	February 5, 1981
Finland	June 25, 1981	
France	June 13, 1980 a/	
Greece	March 3, 1980	
Guatemala	March 12, 1980	
Haiti	April 9, 1980	
Hungary	June 17, 1980	
Ireland	June 13, 1980 a/	
Italy	June 13, 1980 a/	
Luxembourg	June 13, 1980 a/	
Morocco	July 25, 1980	
Netherlands	June 13, 1980 a/	
Panama	March 18, 1980	
Paraguay	May 21, 1980	
Philippines	May 19, 1980	September 21, 1981
Poland	August 6, 1980	
Romania	January 15, 1981	
South Africa	May 18, 1981	
Soviet Union	May 22, 1980	
Sweden	July 2, 1980	August 1, 1980
United Kingdom	June 13, 1980 a/	
United States	March 3, 1980	July 30, 1981
West Germany	June 13, 1980 a/	
Yugoslavia	July 15, 1980	

a/Signed as member of EURATOM.

Source: International Atomic Energy Agency Bulletin, June 1981.
Department of State.

DEPARTMENT OF STATE
Comptroller
Washington, D.C. 20520

1 APR 1982

Mr. Frank C. Conahan
Director
International Division
U.S. General Accounting Office
Washington, D.C.

Dear Frank:

I am replying to your letter of March 10, 1982, which forwarded copies of the draft report: "U.S. Ability to Control and Monitor Weapons-Grade Uranium Supplied Abroad is Limited".

The enclosed comments on this report reflect the views of the Acting Assistant Secretary in the Bureau of Oceans and International Environmental and Scientific Affairs.

We appreciate having had the opportunity to review and comment on the draft report. If I may be of further assistance, I trust you will let me know.

Sincerely,

Roger B. Feldman

Enclosure:

As Stated.

GAO note: We have modified the report to reflect information provided by those commenting on the report.

GAO DRAFT REPORT: "U.S. ABILITY TO CONTROL AND MONITOR WEAPONS-GRADE URANIUM SUPPLIED ABROAD IS LIMITED"

The Department of State has reviewed the above-mentioned draft report, and has the following comments. Additional comments of a technical and factual nature were supplied independently to members of your staff on March 18, 1982. [See GAO note.]

We agree with the report's conclusion on p. 70 that "reducing the use of highly enriched uranium is a sound non-proliferation objective." National Security Decision, Directive Number 6, July 16, 1981 signed by President Reagan, mandates action by the Secretary of State and other agencies "to substitute lower enriched fuels for research reactors at the earliest possible time." With respect to such action, procedures established pursuant to the Nuclear Non-Proliferation Act of 1978 (NNPA), 43 FR 2536 (1978), assign responsibility to the Department of State for coordinating Executive Branch judgment and its submission to the Nuclear Regulatory Commission (NRC), for highly enriched uranium (HEU) license applications. In conjunction with the Reduced Enrichment for Research and Test Reactor (RERTR) program managed by the Department of Energy (DOE), the Department of State is taking steps to limit the export of HEU as soon as it is technically and economically feasible. Attached is a copy of the section of the Report to the Congress, (issued December 31, 1981), as required by section 602 of the NNPA, on this topic, which outlines the steps we are taking and the schedule we hope to meet. With a sustained RERTR program, most foreign research reactors should be convertible to use of low enrichment fuel by 1987/88.

We agree with the recommendation to the Secretary of Energy on p. 17 of the report that "the regulatory authority to accept spent U.S. highly enriched uranium be extended." Not only should it be extended, but it should include authority to accept the new low enrichment uranium (LEU) research reactor fuels that will replace the currently used HEU fuels. Without such a commitment by the United States in the near future, implementation of the RERTR program will be significantly delayed, since major countries will be unlikely to authorize research reactor operators to use LEU fuel, unless the U.S. agrees to take back the fuel for reprocessing (for other disposition), as has been done to date for HEU fuels (33 FR 30 (1968)).

We note the report's concern on p. 50 that there may be a discrepancy between our international policy of reducing use of HEU in research reactors abroad, and the attitude of U.S. domestic research reactor operators. Although the latter

GAO note: The March 18, 1982, comments were provided informally and appropriate changes were made to the report. It should also be noted that page number references in DOE's comments have been changed to reflect page references in the final report.

is primarily an issue of domestic policy, we believe that a consistent approach would benefit our overall non-proliferation goals. Full scale testing of LEU fuels has not yet advanced to the stage where conversion of either foreign or domestic reactors to use of such fuel is presently feasible. Several years of further test work on fuels by DOE are needed. Recent proposed changes in NRC safeguards requirements, 46 FR 46333 (1981), will provide an incentive to NRC licensed U.S. reactor operators to convert to use of LEU fuels, when they become available.

We also note concern in the report on p. 50 about the absence of a viable U.S manufacturer of LEU fuel in the commerical market and the impact this may have on the reduced enrichment program. It is our understanding that the DOE (RERTR program) has entered into contract with a U.S. manufacturer for the transfer of LEU plate-type fuel technology. DOE may be able to furnish more specific information concerning this program for LEU fuel production and whether it is likely to lead to U.S. industrial participation in the commercial market. In addition, rod-type fuel technology has been developed by a U.S. commercial manufacturer and testing of this fuel is partially supported by the RERTR program. In view of these developments, concern for the weakness in the U.S. RERTR program, namely, absence of U.S. LEU fuel manufacturers, both for the U.S. Government and commercially, may be unduly pessimistic.

We note the concern in the report for the capacity of the IAEA adequately to apply safeguards to weapons grade material. Much of this concern, however, appears to be based on misundertanding. Thus, comment on pp. i and ii of the digest and on p. 29 implies that the total amount of HEU exported since 1954 is still abroad and readily available for conversion into nuclear explosive devices. However, most HEU abroad is contained in irradiated fuel elements, not easily convertible into weapons-grade material. This fact and the limited number of reprocessing facilities available have an important bearing on the level of the IAEA inspection effort. Except for two large critical assemblies, the safeguarding task for the IAEA with respect to HEU is fairly straightforward and we have no reason to believe the IAEA is not doing an adequate job. This issue is of prime importance to the Department of State in furtherance of non-proliferation policy, and close interaction with the IAEA is maintained.

We also note, on p. 19, in relation to physical protection, the statement that "the United States receives no information from the IAEA in relation to review trips." The IAEA has no statutory basis for conducting physical protection reviews.

We believe that certain of the findings do not sufficiently take into account: 1) the significance of the current strict U.S. export controls over HEU supply; 2) the relatively few countries which are deemed eligible to receive kilogram quantity HEU exports; 3) the need to distinguish between exports of significant quantities of HEU for fueling research reactors and gram quantities for industrial and research purposes which are not significant from a proliferation standpoint; and 4) the need to distinguish between the national sovereign responsibility of each nation with a nuclear program to apply appropriate physical security measures and the international responsibility, administered by the IAEA, to apply safeguards.

In summary, the Department of State generally agrees with the recommendations of the draft report, and believes it will make a positive contribution to overall U.S. nuclear non-proliferation policy development.

Charles Horner

Charles E. Horner
Acting Assistant Secretary
Bureau of Oceans and International
Environmental and Scientific
Affairs

Department of Energy
Washington, D.C. 20585

APR 15 1982

Mr. J. Dexter Peach
Energy and Minerals Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

This refers to your letter of March 10, 1982, to Secretary Edwards, enclosing, for Department of Energy (DOE) review and comment, the draft GAO report entitled "U.S. Ability to Control and Monitor Weapons - Grade Uranium Supplied Abroad is Limited."

The interested DOE offices have reviewed the subject report and have met with your representatives to provide DOE's comments in the interest of producing a more balanced and accurate picture of the status of the various issues addressed in the report. While we agree, in part, with some of the recommendations, we believe major efforts should be made to give the report greater balance. More specific comments follow:

Overall we do not believe the document presents an entirely fair and accurate picture of the efforts the United States has had underway - both in the current and previous Administrations - to phase out the use of highly enriched uranium (HEU) for use in research reactors where found to be technically and economically feasible. This is most unfortunate since from the very beginning of the U.S. international nuclear program there has been an appreciation that unirradiated HEU merits special caution and attention in export processing, and over recent years, progress has been made in moving to lower enrichments. Also, in some instances, the threats described in the GAO report are overstated, and neither the Executive Branch nor NRC are given fair credit for efforts already underway that are consonant with GAO's recommendations. Further, there is an erroneous implication - that the current Administration is treating this area of concern in a more relaxed manner than the previous one. Accordingly, while we believe that substantially more work needs to be done to encourage nations around the world to actually shift to lower enrichments, in our view, the report should be rewritten to present a more factually accurate and balanced picture of where we stand in the process.

GAO note: We have modified the report to reflect information provided by those commenting on the report.

Criteria for Review

The digest of the report, under the caption "U.S. Controls Over Highly Enriched Uranium" indicates that the relevant agencies follow the same general export license criteria and review process procedures for subsequent arrangements for highly enriched uranium as they do for low enriched uranium. We are concerned that this gives a misleading picture of what occurs, when in fact, all proposed exports of HEU are subject to rigorous inter-agency review (supported by analytical studies by the Argonne National Laboratory) with the view of encouraging cooperating nations to phase out the use of highly enriched uranium as soon as technologically and economically feasible. The fact that reports resulting from such efforts are no longer submitted to the President is a reflection of a desire to simplify the procedures, but the criteria that we are employing in reviewing cases remain the same as those adopted by the previous Administration. Our evaluations have been supported by analytical studies conducted by the DOE Reduced Enrichment Research and Test Reactor (RERTR) Program as well as cooperation by U.S. industry and foreign fuel fabricators and users. For example, as a general rule U.S. manufactured and deployed TRIGA reactors around the world will use 20 percent enriched uranium for all fuel replacements, and we are hopeful that many larger test reactors also will convert to lower enrichments when such replacement fuels become available. To place this matter in perspective it must be understood, however, that the DOE RERTR program is addressed to developing the technology of lower enriched fuels to the point where they can be put to practical application with the assent of foreign and domestic reactor operators - including foreign licensing and regulatory authorities. The actual deployment of such fuels by foreign reactor operators is not within DOE control.

Reprocessing

The GAO report appropriately notes the importance of U.S. acceptance (for reprocessing) of spent highly enriched uranium of U.S. origin from other nations. While the report recommends that this program of acceptance be extended, it implies that DOE has not been sufficiently active in encouraging such returns, that our financial terms for reprocessing are an impediment in this regard, and that this in turn is leading to a less than satisfactory situation given the inventories of U.S. origin HEU still overseas. In our view, the report should be modified to reflect the following points:

- First, it should be stressed that DOE has had active plans underway, for several months, to extend the U.S. offer to reprocess U.S. origin HEU irradiated in research reactors. We intend that the offer will be extended before the current Federal Register Notice expires at the end of 1982.

- Second, with reference to the GAO report assertion that only a small fraction of U.S. origin fuel has been returned to the U.S., we believe it is important to note that in most cases the fuel involved is in irradiated form overseas, either in reactors (some of which use a core load for several years before discharge), or in spent fuel storage basins. Irradiation of HEU produces very small amounts of plutonium, and the HEU itself cannot be employed in a nuclear weapon unless a country is able to separate out the highly radioactive fission waste products. Only a few nations have such capabilities.

- Third, with reference to the assertion that our minimum reprocessing charges are serving as a disincentive to some countries to return fuel to the U.S., we believe there is sufficient flexibility in existing U.S. policy to permit several small users to combine their batches. This is a step we have encouraged in the past and intend to encourage to a greater degree in the future. Given our obligation to recover our full costs in such situations, however, we do not anticipate that it will be feasible for us to reduce our charges. The minimum batch charge reflects an estimate of the cost of providing processing services for small quantities of material. It is composed of costs for start-up of process systems, recovery operations, and plant cleanouts for materials accountability. Operations conducted before and after fuel dissolution and uranium purification are for the most part insensitive to the actual quantity of fuel processed; therefore, it is logical that the costs on a per kilogram basis for processing small quantities of fuels will be higher than larger batches.

- Fourth, DOE is now considering the incorporation of provisions in the Federal Register Notice for acceptance of irradiated aluminum-uranium research reactor fuels below the 20 percent range, and a study concerning reprocessing of uranium-silicide fuels is now underway.

Physical Security

The digest caption in the GAO report entitled "Limited U.S. Ability to Assure Adequate Physical Protection" suggests that the U.S. is not receiving timely and sufficient facility specific data on the physical security measures that apply to U.S. origin HEU fuel shipped overseas. The suggestion also is made that cooperating states have not been sufficiently forthcoming in giving us the data or access we need to make timely judgments. We believe that this is a misleading conclusion that overlooks several important factors, including the following: most countries voluntarily adhere to the IAEA's guidelines on physical security and have their own independent reasons for wishing to protect their nuclear installations from dissident or terrorist groups; the London Nuclear Suppliers Group has also agreed on minimum physical security requirements for exports of HEU. Under a U.S. initiative, an international convention on physical security of nuclear materials has been approved by 34 countries.

Although there was some initial resistance in 1974 in one of the first countries that a U.S. team visited for a physical security review, this resistance was rapidly changed to a cooperative attitude.

Criteria for initiating visits by U.S. physical security teams include the following:

1. Political unrest or increased terrorist activity in the country since the last visit, or
2. New, or expanded, Category I facilities under consideration or have been put into operation since the last visit, or
3. Significant improvements in physical security have occurred since the last visit, and
4. Consideration of the time since the last visit.

In all of the 41 countries visited one or more times, there has been, in general, excellent cooperation. U.S. physical security teams have visited representative nuclear facilities in each country and all facilities in most countries. In only one country was there reluctance to allow a U.S. team to visit a specific facility; however, U.S. personnel did later visit this facility. Countries view physical security as a national responsibility and not one to be executed by the U.S. or the IAEA. We feel this is a reasonable position; however, the U.S. team has emphasized to each country the mutual benefits to be derived by exchange of information which would improve security systems worldwide. The U.S. has provided suggestions for improvements when appropriate and has held up some exports until systems were upgraded to satisfactory levels. The results of this program have been encouraging. There is an international awareness and concern of the risks, a willingness to cooperate, and commitments to generate upgrading programs where needed.

The report should also mention that the U.S. is providing training courses under IAEA sponsorship in physical security systems.

Character of the Material Overseas and its Location

We also believe it is important to make two general comments on the total volume of U.S. exports of HEU. First, of the 16,000 kilograms that has been exported, about 300 kgs of HEU is dispersed in fairly small inventories to a total of 25 countries. Few of these countries have enough material to make a nuclear explosive.

Furthermore, almost all of this material was exported in fabricated fuel element form, and only exported on an as needed basis, e.g., when new fuel was needed or after return to the U.S. of spent fuel. Thus, this material in these 25 countries, in our view, does not constitute a significant proliferation risk. Second, the remainder of the 16,000 kilograms which has been exported has been transferred to nine countries who ther are close allies of the U.S., weapons states, and/or NPT signatories. These are Belgium, Canada, France, West Germany, Italy, Japan, The Netherlands, Sweden, and the United Kingdom. The U.S. does not consider these countries to be proliferation risks. However, the U.S. has been concerned about the unauthorized diversion of highly enriched as well as any weapons useable material (Category I material) by a terrorist group. The U.S., particularly in concert with these countries, has placed a premium on ensuring that adequate physical security exists for Category I material. The U.S. took the lead in establishing an international convention on physical security. Before exporting HEU to these nine countries as well as the others, the U.S. must obtain a government-to-government assurance that measures will be maintained to ensure, at a minimum that, the physical security standards set forth in IAEA INFCIRC 225/Rev 1 are maintained. To review physical security measures, the team has visited each of the nine countries within the last two years and has concluded that adequate physical security measures exist in each country for all Category I material, including U.S. origin HEU.

Application of IAEA Safeguards

The section of the report entitled "Common Safeguards Problems Limit Ability to Detect Diversions of Highly Enriched Uranium" argues that the IAEA is not inspecting research reactors that use HEU with sufficient frequency and states that many such facilities are not being visited even once a year because they are minor and possess less than 25 kilograms of HEU. GAO says that this practice is inadequate. We wish to emphasize that in our view IAEA inspections and related safeguards measures can provide reasonable assurances that no HEU has been diverted from a research reactor. To place this matter in perspective, based on our review of the latest available IAEA evaluation, it is our understanding that at the end of 1980 the IAEA had 175 research reactors and critical assemblies under inspection, and that 131 of these possessed less than one significant quantity (SQ) of material - a quantity the equivalent of 25 kgs of HEU, 75 kgs of uranium with enrichments below 20 percent, or 10 metric tons of natural uranium. Also, our mission in Vienna advises that in a typical 12-month period about three-fourths of the research reactors and critical facilities containing less than one significant quantity of enriched uranium were in fact inspected. Of those not inspected, almost all contained less than one-tenth of a significant quantity. [See GAO note on next page.]

Research reactors possessing more than one significant quantity of fissile material are inspected more often, with the frequency governed by the size and characteristics of the project, the quantities of non-irradiated HEU likely to be involved, as well as the potential opportunities for plutonium production. Most of the material in these facilities typically is in the core or in the form of irradiated spent fuel. The GAO report fails to mention that only a few nations have the capability to recover residual HEU from irradiated spent fuel.

While one cannot discount the diversion scenarios for possible large scale research reactors, we believe that the IAEA is acting prudently in giving its priority safeguards attention to bulk handling facilities such as reprocessing plants or HEU fabrication plants, rather than squandering its resources on minor research reactors. IAEA attention obviously has to be devoted to those cases or situations involving the greatest quantities or production of weapons usable materials, and we believe it would be a misallocation of IAEA resources to shift substantial resources to research reactors possessing less than one significant quantity of material. We are not aware of any diversion of HEU under IAEA safeguards, and the IAEA has reported continual progress in upgrading its safeguards procedures at research reactors.

GAO note: DOE comments do not address the inspection activities at facilities with more than a significant quantity of material or the ability of IAEA to meet its own detection goals at such facilities. It should be noted that the facilities not inspected in 1980 included some with more than a significant quantity of unirradiated HEU. When considering inspections during a one-year period, it should be remembered that (1) the approximate time to convert unirradiated HEU for use in a nuclear explosive device is 7 to 10 days and 1 to 3 months for irradiated HEU and (2) IAEA carried out about 50 percent of its estimated routine inspection effort due to inspector shortages.

Additionally, during conversations subsequent to the issuance of these comments, DOE officials advised us that the "typical 12-month period" was 1980 and that the "three-fourths" should be two-thirds.

Tracking Nuclear Materials

The portion of the digest captioned "Central Tracking System Is Inaccurate and Unreliable" characterizes the Department of Energy's central computerized system used for tracking all U.S. exported highly enriched uranium as incomplete and inaccurate. Unidentified intended users are described as considering the system "inadequate, inflexible and unreliable". The report also suggests that DOE is not effectively using all of the information available to it and has suggested that DOE better integrate the various information systems that it employs for tracking such materials.

As you know, DOE has had a major effort underway to upgrade its tracking system, bearing in mind that for years records were not computerized. We believe useful progress is being made. Also, in accordance with GAO's suggestion, we are initiating a review to see whether a better integration can be achieved of the different systems even though they are designed to serve different purposes. For instance, NRC's IPELTS system is designed to provide only computerized information on export licenses. The NMMSS/INMTS systems are not designed to track the movement of U.S. origin materials within a cooperating nation. If we moved in this direction, we would have to impose an entire series of new reporting requirements on cooperating countries which could be resented by most of them. Also, such a requirement is not easily justifiable since all of our exports are already subject to IAEA or Euratom accountability and verification. We look to these bodies to perform the basic safeguards functions to help determine that no diversions occur. In addition, under our newer agreements for cooperation, the cooperating nation authorizes the IAEA to provide us with inventory data.

To elaborate on the tracking situation, the following additional comments should be made.

The INMTS was conceived in 1977 to automate a manual system of records dating from 1954 pertaining to the international transfer of U.S. origin nuclear materials. The automation was completed in 1978, and a subsequent audit was performed to determine the accuracy and completeness of the data base. The data base was found to have serious problems, and a "verification" project was planned to compare the data base with all pertinent available sources of data in the United States and to correct the deficiencies to the extent possible. This project will be completed in 1982, and we believe the INMTS will then be able to perform those functions it has been delegated with an acceptable degree of accuracy. A recent reconciliation of the "verified" U.S. data with that of Australia supports this opinion.

The mission of the INMTS is to record and maintain export, import, and retransfer data for U.S. origin material. However, the way this issue is treated in the report leads us to believe this is not clearly understood by the GAO.

For example, the report states on page 48, "Our review showed that the NMMSS/INMTS international tracking system is not reliable for monitoring HEU supplied overseas for the following reasons:" and lists as one reason, "...The system shows where the material was originally shipped, but may not identify current location of the exported HEU. Moreover, the system does not show the current physical status of the material (e.g., irradiated, fabricated, or reprocessed)." It should be noted that INMTS was never intended to monitor either the location within the national boundaries of the recipient foreign entity or the physical status of the material.

It should be made clear, however, that INMTS does not track the disposition of HEU within a country. DOE has developed a system designed to address worldwide plutonium generation and utilization. This system, the Special Nuclear Materials Tracking System (STAMAS), is designed to address the generation and utilization of plutonium in the commercial nuclear fuel cycle. Recently, discussions have been initiated on the desirablility and feasibility of addressing research facilities and materials such as highly enriched uranium. Should HEU data be monitored by STAMAS, this system would utilize the NMMSS/INMTS data as a portion of its input. One other point should be made -- although the STAMAS does address "tracking," the system is not an accountability system and cannot provide accountability data.

Terrorist Threats

Finally, the report seems to imply that some, and perhaps a number of, terrorist acts have involved group efforts "to divert special nuclear material for making explosive devices." DOE has no information that indicates such organized efforts on the part of terrorist groups, and barring GAO's possession of some definitive information to this effect the statement seems misleading.

A second concern is the suggestion that all 39 incidents referenced by GAO were "terrorist initiated." While we do not wish to underrate this area of concern, a check of Appendix VI indicates that very few of the 39 incidents were terrorist inspired. With the discussion developed under a section entitled "Concerns Over Nuclear Terrorism..." the lay reader, however, is left with the impression that more acts of nuclear terrorism have occurred than in fact clearly is the case. Our concerns are that a labeling of almost any criminal act targeted against nuclear facilities as "terrorist" may tend to confuse the analysis and the evaluation of threats. It is recommended that GAO establish a clearer definition in the report of what it means by a terrorist--group or individual--and in particular what is meant by the term nuclear terrorism. Then all reference to the history of acts of nuclear terrorism would meet the report's definition of the phenomenon being analyzed.

We would urge you to factor our comments into the final version of your report. A copy of this letter, as well as an annotated copy of the referenced draft audit report, have been provided directly to your staff.

Sincerely,

William S. Heffelfinger
Assistant Secretary
Management and Administration

UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY
Washington DC 20451

April 1, 1982

Dear Mr. Conahan:

Enclosed are ACDA's comments on the U.S. General Accounting Office report "U.S. Ability to Control and Monitor Weapons Grade Uranium Supplied Abroad is Limited."

Sincerely,,

Thomas Graham, Jr.
Director, Office of
Congressional and
Public Affairs

Enclosure:

ACDA Comments on GAO Report.

Mr. Frank C. Conahan
Director
International Division
United States General
Accounting Office

GAO note: We have modified the report to reflect the information provided by those commenting on the report.

ACDA General Comments on GAO Report

CHAPTER 1

It is worth noting that the overwhelming majority of HEU exported from the US has been to US allies, and that at present virtually all HEU exports are to such countries. This fact alone tends to reduce significantly the possibility of national diversion of any HEU that continues to be exported from the US, and places the principal risk in the area of theft either by a terrorist group or an outlaw nation.

CHAPTER 3

ACDA agrees with the GAO conclusion that the problem of physical security for nuclear materials warrants increased attention in view of the increase in the number and sophistication of terrorist activities and the increase in the amount of HEU and mixed (plutonium plus uranium) oxide materials being transported within and between national boundaries. ACDA will work with NRC and other Executive Branch agencies to ensure a common understanding of the physical protection problems facing the US and foreign governments so that uniform physical security measures will be applied which will adequately protect nuclear materials in transit, both now and in future circumstances. As more countries expand their involvement in international nuclear fuel cycle commerce, particularly in mixed oxide materials, it will become increasingly important that international norms be established which provide adequate and consistent physical protection of nuclear materials, particularly in transit.

CHAPTER 4

ACDA agrees with the general thrust of GAO comments that there is a need for increased IAEA resources for inspecting HEU and that there are certain difficulties being encountered by the IAEA in applying its safeguards to HEU.

There are, however, a number of points made in the draft report which are general in nature and whose relevance, if any, to safeguarding HEU should be indicated. In addition, the comments in the report on the risks that diversion of HEU might go undetected for long periods of time should be put in the context of the very limited risk, in most countries, that diverted material, i.e., irradiated fuel assemblies, could be reprocessed and the purified uranium recovered. [See GAO note.]

GAO note: Our comments on IAEA safeguards are necessarily general because (1) we do not have audit authority at IAEA, (2) IAEA does not make public specific information about safeguards implementation, and (3) some information we had hoped to include in a discussion of safeguards over HEU was classified by the executive branch and therefore was not included in this report.

CHAPTER 6

ACDA agrees strongly with GAO that reducing the use of HEU abroad is a sound non-proliferation objective. Furthermore, the issues identified by GAO which require resolution before foreign reactors actually convert to LEU fuels are precisely those which the Executive Branch is giving high priority to resolving. For example, ACDA along with other Executive Branch agencies has diligently supported the funding level of the RERTR program in the FY 83 budget necessary to complete the program as expeditiously as possible. The technical and political problems associated with the take-back and reprocessing of foreign research reactor spent fuel are being addressed, and a resolution of these problems is expected within the next year or so. Personnel in the RERTR program and Executive Branch are working with foreign governments and reactor operators to address the technical and licensing problems which must be solved before reactors are actually converted; and a spirit of international cooperation and optimism toward accomplishing the program's objectives continues to be demonstrated at the international meetings of the program participants. Finally, RERTR program personnel are working closely with a U.S. fuel vendor to transfer advanced fuel fabrication technology, which could make a U.S. vendor a competitor for most of the world's research reactor fuel orders.

GAO note: ACDA also suggested clarifying language and editorial changes. These have been deleted here, however appropriate changes were made to the report.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

APR 12 1982

Mr. J. Dexter Peach, Director
Energy and Minerals Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Peach:

This is in response to your letter of March 10, 1982, requesting comments on the draft report to the Congress entitled, "U.S. Ability to Control and Monitor Weapons-Grade Uranium Supplied Abroad is Limited." The draft report has been reviewed by the Nuclear Regulatory Commission staff. In addition to the general comments below, detailed comments are enclosed.

The subject of the report is a complicated one. Although considerable information is presented, the report needs to achieve better balance and perspective and to avoid focusing on events or circumstances in isolation. In addition, the report sometimes generalizes too broadly. These concerns arise particularly in connection with Chapters 3, 4, and 5 which address physical protection, international safeguards and material tracking systems. For example:

-- It should be clearly pointed out that exports of Highly Enriched Uranium are given comprehensive inter-agency review of far greater intensity than that applied to most Low Enriched Uranium exports.

-- The discussion of foreign physical protection reviews needs to be put into better perspective by noting that the great majority of HEU has been exported to a limited number of of countries and that exported HEU has received better coverage by U.S. physical security reviews than implied in the report.

-- The discussion of IAEA safeguards in Chapter 4 should be balanced by noting that the IAEA concentrates its inspections on facilities with significant quantities of material like HEU that can be used directly in explosives rather than on small research reactors.

-- Chapter 5 should clarify that no USG agencies currently have responsibility to track U.S.-origin nuclear material abroad and negotiation of international agreements with export recipients would be required to accomplish this.

GAO note: We have modified the report to reflect the information provided by those commenting on the report.

Should you or your staff wish to discuss the report and our comments in more detail, please let us know.

Sincerely,

William J. Dircks
Executive Director
for Operations

Enclosure:
As stated

GAO note: Although not reprinted here, technical comments and proposed editorial changes provided by NRC have been incorporated, where appropriate, throughout the report. However, we believe it is important to note that in its technical comments NRC agreed with the recommendation that information on U.S.-supplied nuclear material should be streamlined and consolidated. Nevertheless, NRC pointed out that it is not clear whether this could be accomplished through development of a single information system.

Our comments on IAEA safeguards are necessarily general because (1) we do not have audit authority at IAEA, (2) IAEA does not make public specific information about safeguards implementation, and (3) some information we had hoped to include in a discussion of safeguards over HEU was classified by the executive branch and therefore was not included in this report.

(465266)

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MICHIGAN MEMORIAL PHOENIX PROJECT
THE UNIVERSITY OF MICHIGAN

SAFETY ANALYSIS

UTILIZATION OF LOW ENRICHMENT URANIUM (LEU) FUEL IN THE FORD NUCLEAR REACTOR

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FORD NUCLEAR REACTOR
MICHIGAN MEMORIAL - PHOENIX PROJECT
THE UNIVERSITY OF MICHIGAN
Ann Arbor

October, 1979

Prepared For
U.S. Nuclear Regulatory Commission

SAFETY ANALYSIS

UTILIZATION OF LOW ENRICHMENT URANIUM (LEU) FUEL IN THE FORD NUCLEAR REACTOR

FORD NUCLEAR REACTOR
MICHIGAN MEMORIAL-PHOENIX PROJECT
THE UNIVERSITY OF MICHIGAN
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ABSTRACT

This analysis reviews the safety aspects of utilizing low enrichment uranium (LEU-less than 20% enrichment) fuel in the Ford Nuclear Reactor (FNR). A brief description of the proposed fuel is followed by an examination of fuel swelling, high temperature blistering, and failure data for similar operational and test fuels under operating conditions similar to those in the FNR. Fuel specifications have been developed with technical requirements identical to those for reactors which use equivalent fuel. Heat transfer characteristics are not examined in detail because fuel and coolant flow channel dimensions are identical to those in present FNR fuel. Core physics analyses show some variation in fast and thermal neutron flux distributions within the core and in the reflector regions. The available data and the analyses performed indicate that no reduction in safety margins are expected from utilizing LEU fuel in the FNR core.

1. INTRODUCTION

As part of the national plan for development of high uranium density research and test reactor fuel to accomodate the use of low enrichment uranium (LEU) fuel, the Ford Nuclear Reactor (FNR) proposes to test the use of 19.5 wt% enriched uranium fuel in the form of uranium aluminide (UAl_x) or uranium oxide (U_3O_8) in place of the present 93 wt% uranium aluminide fuel.

The use of less than 20% enrichment fuel gives the potential benefit of reducing the probability of uranium-235 diversion. An additional benefit is a possible reduction in the cost of security requirements for both fuel fabrication and fuel handling and storage.

This report includes information on fuel which is physically similar to the proposed LEU fuel and which has been satisfactorily tested under operating conditions similar to those of the Ford Nuclear Reactor.

Core physics calculations indicate that utilization of LEU fuel in the FNR core will result in a decrease in thermal flux of 12-20% in the core region and a decrease of 6-10% in the reflector region.

2. FUEL DESCRIPTION

The proposed LEU fuel meat is to be intermetallic uranium aluminide (UAL_3, UAL_4, UAL_2) or uranium oxide (U_3O_8) cermet, both of which are licensed for use by the FNR, clad in 6061 aluminum.

Fuel element overall dimensions and internal dimensions will remain identical to the dimensions of fuel presently being used in the FNR at two megawatts. Plate thickness will be 0.060 inches. The meat will be 0.030 inches and cladding 0.015 inches. Two plate thicknesses are presently in use at the FNR. Uranium-aluminum alloy fuel plates are 0.060 inches thick with 0.020 clad-0.020 meat-0.020 clad. Aluminide fuel plates are 0.050 inches thick with 0.015 clad-0.020 meat-0.015 clad. The FNR has operating experience with fuel plates which are 0.060 inches thick and which have 0.015 inch clad, and no problems have arisen.

The proposed meat thickness of 0.030 inches is dictated by an attempt to provide fuel with the same reactivity as present FNR fuel while reducing the enrichment from 93% to just under 20%. In order to provide the proper uranium-235 loading, the weight percent of the fissile compound in the fuel meat must be increased from the present 19.1 weight percent UAL_x or 16.8 weight percent U_3O_8 to approximately 56.5 weight percent UAL_x or 49.6 weight percent U_3O_8. Present uranium loading is 14.2 weight percent; the proposed loading is 42.0 weight percent.

3. OPERATING CONDITIONS

Fuel swelling data and fuel blister data, which were obtained for fuel plates made of materials similar to those in the FNR and which were determined at fuel temperature, pressure, and pH conditions similar to FNR conditions, were extracted from the data contained in reports referenced in the Safety Analysis bibliography and are tabulated in TABLE 1 and TABLE 2. All available data points are included.

The aluminum powder used in the proposed FNR fuel and in the test cores is a blend of nearly pure aluminum. 1100 aluminum is pure aluminum. The various powder blends (PB-01, PB-04, PB-32, PB-36) are essentially pure aluminum of specific grain sizes. 5214 is spherical aluminum powder with .05% iron and a total of .03% iron plus silicon permitted. X8001 is a nickel alloy of aluminum which is only slightly harder than 1100.

4. FUEL SWELLING

Table 1A provides UAL_x fuel swelling data.[1, 2, 3, 4, 5] Table 1B contains U_3O_8 fuel swelling data.[4] Test temperatures are as close as possible to the FNR peak operating temperature of 172°F. All test data were obtained at significantly higher pressures. Figure 1 is a plot of the UAL_x and U_3O_8 data points. Also shown on Figure 1 is the FNR fission density limit of 15×10^{20} fissions/cc and the calculated swelling rate for 100% dense fuels.

With the exception of one data point, the measured swelling rate is below the calculated swelling rate. It is expected that the measured swelling rate would be less than calculated because some voids are expected in core compacts and voids generally tend to reduce swelling.

No fuel failures were observed for the fission density-fuel swelling combinations plotted on Figure 1. Therefore, all of the available fuel swelling data at operating conditions similar to those in the FNR indicate that UAL_x and U_3O_8 fuel can be safely used in the FNR without failure due to swelling and that no reduction in the safety margin is expected.

5. FUEL BLISTERING

Table 2A provides UAL_x fuel blister data.[1, 2, 3, 5, 7] Table 2B contains U_3O_8 fuel blister data.[1, 8] Figure 2, a plot of fuel blister temperature verus fission density for the Table 2A and 2B data, shows that all blister failures occurred in fuel being operated at temperatures well above the FNR peak operating temperature of 172°F.

TABLE 1A

UAL_x FUEL CORE SWELLING DATA

Reactor	Fuel Characteristics									
Sample ID	Clad	Core	Weight Percent UAL_x	Weight Percent U	Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Volume Change % ΔV/V	Ref
FNR	6061	5214	19.1	14.2	172 (78)	9.2	5-7	15.0		
MTR										
113-1	6061	6061	46.7	34.7	239 (115)	50	5-7	7.5	7.5	1
113-2	6061	6061	46.7	34.7	239 (115)	50	5-7	10.1	6.8	1
113-3	6061	6061	46.7	34.7	239 (115)	50	5-7	9.4	6.2	1
113-4	6061	6061	46.7	34.7	239 (115)	50	5-7	9.8	3.7	1
113-5	6061	6061	46.7	34.7	239 (115)	50	5-7	13.5	7.3	1
113-6	6061	6061	46.7	34.7	239 (115)	50	5-7	14.1	7.3	1
113-7	6061	6061	46.7	34.7	239 (115)	50	5-7	14.5	5.5	1
ETR										
I-1-1095	6061	X8001	51.0	37.9	230 (110)	200	5-7	6.9	0.8	2
I-1-1097	6061	X8001	51.0	37.9	230 (110)	200	5-7	5.6	0.8	2
I-12-727	APM786	X8001	51.0	37.9	230 (110)	200	5-7	10.9	3.9	2
I-1-584	6061	X8001	51.0	37.9	302 (150)	200	5-7	7.2	0.6	2
I-69-1579	6061	MD101	60.0	44.6	302 (150)	200	5-7	16.5	3.6	2
I-71-1594	6061	MD101	77.0	57.2	302 (150)	200	5-7	24.7	1.1	2
I-69-1580	6061	MD101	60.0	44.6	338 (170)	200	5-7	9.4	1.8	2
I-70-1583	6061	MD101	65.0	48.3	338 (170)	200	5-7	11.0	1.2	2
I-70-1584	6061	MD101	65.0	48.3	338 (170)	200	5-7	16.2	4.9	2

TABLE 1A

UAL_x FUEL CORE SWELLING DATA

Reactor	Fuel Characteristics									
			Weight Percent							
Sample ID	Clad	Core	UAL_x	U	Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Volume Change % $\Delta V/V$	Ref
FNR	6061	5214	19.1	14.2	172 (78)	9.2	5-7	15.0		
ETR										
169-4	6061	X8001	61.9	46.0	228 (109)	200	5-7	26.3	2.0	3
169-5	6061	X8001	61.9	46.0	228 (109)	200	5-7	28.8	4.7	3
169-11	6061	X8001	52.0	38.7	228 (109)	200	5-7	23.1	4.7	3
169-12	6061	X8001	52.0	38.7	228 (109)	200	5-7	24.3	5.9	3
169-19	6061	X8001	43.0	32.0	228 (109)	200	5-7	19.7	4.7	3
169-36	6061	X8001	52.8	39.2	228 (109)	200	5-7	25.1	6.4	3
169-37	6061	X8001	52.7	39.2	228 (109)	200	5-7	25.5	6.0	3
169-38	6061	X8001	52.7	39.2	228 (109)	200	5-7	25.0	7.4	3
169-39	6061	X8001	52.7	39.2	228 (109)	200	5-7	23.9	5.7	3
HFIR										
32-4	6061	PB-32*	51.0	37.9	176 (80)	1000	5-7	17.9	8.8	4
34-2	6061	PB-36	53.0	39.4	190 (88)	1000	5-7	19.5	6.8	4
14-3	6061	PB-32	53.0	39.4	198 (92)	1000	5-7	20.2	7.4	4
15-4	6061	PB-32	63.0	46.8	208 (98)	1000	5-7	22.2	6.1	4
35-4	6061	PB-36	63.0	46.8	201 (94)	1000	5-7	21.4	4.8	4
25-4	6061	PB-32	64.0	47.6	205 (96)	1000	5-7	21.7	4.1	4

* Aluminum Powder Blends

TABLE 1A

UAL_x FUEL CORE SWELLING DATA

Reactor	Fuel Characteristics									
Sample ID	Clad	Core	Weight Percent UAL_x	Weight Percent U	Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Volume Change % $\Delta V/V$	Ref
FNR	6061	5214	19.1	14.2	172 (78)	9.2	5-7	15.0		
FR2 (Kalsruhe, Germany)										
1-4	1100	1100	50	37.1	158 (70)	50	5-7	5.8	2.0	5
2-4	1100	1100	50	37.1	158 (70)	50	5-7	16.9	4.5	5
3-4	1100	1100	50	37.1	158 (70)	50	5-7	12.2	4.0	5
4-1	1100	1100	50	37.1	158 (70)	50	5-7	9.4	3.5	5
5-3	1100	1100	45.5	33.8	158 (70)	50	5-7	9.4	3.5	5
6-4	1100	1100	45.5	33.8	158 (70)	50	5-7	7.6	4.0	5
7-2	1100	1100	50	37.1	158 (70)	50	5-7	15.8	5.0	5
8-2	1100	1100	45.5	33.8	158 (70)	50	5-7	15.8	4.0	5

TABLE 1B

U_3O_8 FUEL CORE SWELLING DATA

Reactor	Fuel Characteristics									
			Weight Percent							
Sample ID	Clad	Core	U_3O_8	U	Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Volume Change % ΔV/V	Ref
FNR	6061	5214	16.8	14.2	172 (78)	9.2	5-7	15.0		
HFIR										
12-3	6061	PB-01*	47	39.7	192 (89)	1000	5-7	19.8	3.0	4
13-4	6061	PB-01	40	33.8	183 (84)	1000	5-7	18.1	3.8	4
22-4	6061	PB-04	50	42.3	187 (86)	1000	5-7	19.7	2.9	4
23-1	6061	PB-04	42	35.5	181 (83)	1000	5-7	18.1	3.1	4
ETR										
67-974	6061	PB-01*	40	33.8	401 (205)	200	5-7	17.9	4.7	4
67-982	6061	PB-01	40	33.8	383 (195)	200	5-7	18.0	5.1	4
67-986	6061	PB-01	40	33.8	392 (200)	200	5-7	18.1	6.2	4
56-899	6061	PB-01	50	42.3	302 (150)	200	5-7	11.7	1.4	4
56-957	6061	PB-01	50	42.3	302 (150)	200	5-7	22.4	7.6	4
3-893	6061	PB-04	45	38.0	347 (175)	200	5-7	15.5	2.0	4
68-997	6061	PB-04	49	41.4	347 (175)	200	5-7	19.7	3.6	4
68-1688	6061	PB-04	49	41.4	428 (220)	200	5-7	12.7	0.4	4
68-1633	6061	PB-04	49	41.4	419 (215)	200	5-7	12.7	0.4	4
68-1642	6061	PB-04	49	41.4	410 (210)	200	5-7	12.7	1.7	4
68-1605	6061	PB-04	49	41.4	329 (165)	200	5-7	19.9	3.0	4
68-1607	6061	PB-04	49	41.4	338 (170)	200	5-7	19.5	3.1	4

* Aluminum Powder Blends

FIGURE 1

FUEL CORE SWELLING

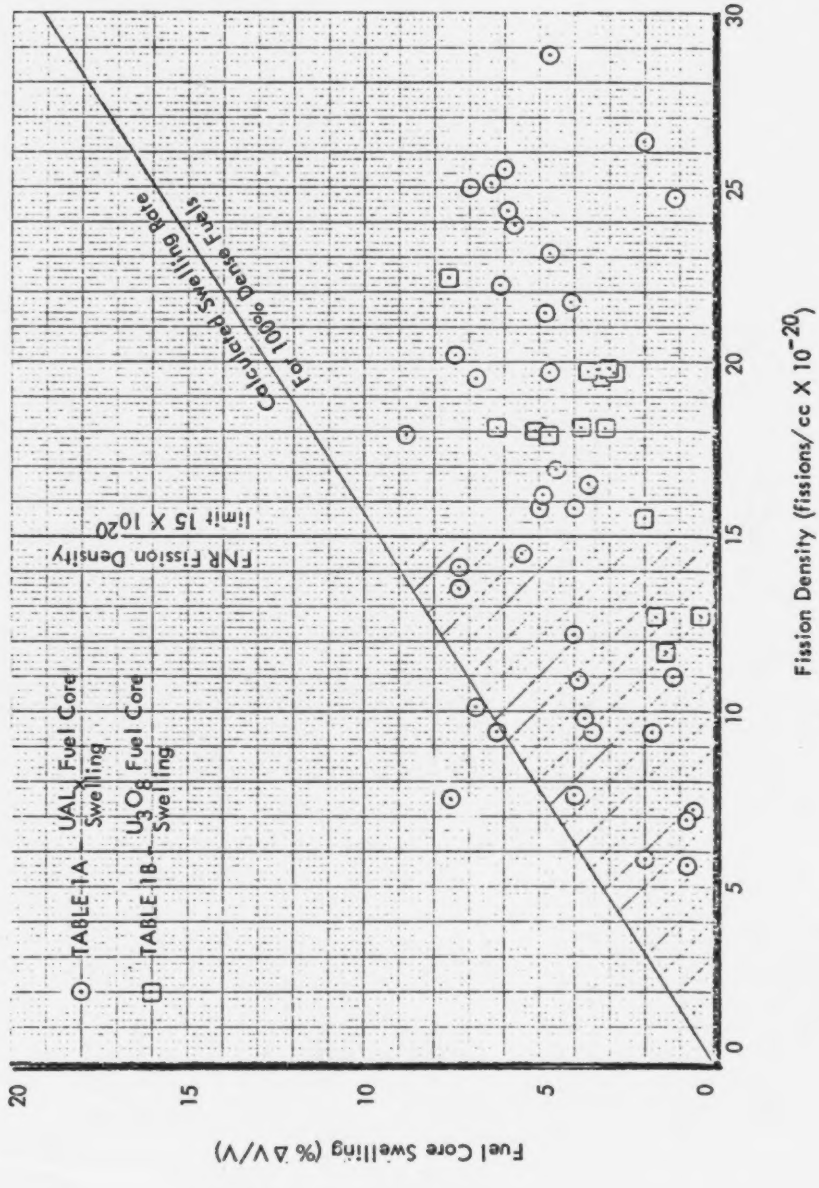


TABLE 2A

UAL_x FUEL CORE BLISTER DATA

Reactor	Fuel Characteristics									
			Weight Percent							
Sample ID	Clad	Core	UAL_x	U	Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Blister Temp, °F (°C)	Ref
FNR	6061	5214	19.1	14.2	172 (78)	9.2	5-7	15.0		
ETR										
E-107	6061	X8001	54.0	40.1	403 (206)	200	5-7	10.4	1094 (590)	7
E-508	6061	X8001	54.0	40.1	403 (206)	200	5-7	10.7	1094 (590)	7
E-510	6061	X8001	54.0	40.1	403 (206)	200	5-7	11.0	1094 (590)	7
E-507	6061	X8001	54.0	40.1	403 (206)	200	5-7	11.2	1094 (590)	7
I-1-1095	6061	X8001	51.0	37.9	230 (110)	200	5-7	6.9	1004 (540)	2
I-1-1097	6061	X8001	51.0	37.9	230 (110)	200	5-7	5.6	1004 (540)	2
I-12-727	APM786	X8001	51.0	37.9	230 (110)	200	5-7	10.9	1004 (540)	2
I-69-1579	6061	MD101	60.0	44.6	302 (150)	200	5-7	7.2	1112 (600)	2
I-71-1594	6061	MD101	77.0	57.2	302 (150)	200	5-7	24.7	806 (430)	2
I-69-1580	6061	MD101	60.0	44.6	338 (170)	200	5-7	9.4	1112 (600)	2
I-70-1583	6061	MD101	65.0	48.3	338 (170)	200	5-7	11.0	1112 (600)	2
I-70-1584	6061	MD101	65.0	48.3	338 (170)	200	5-7	16.2	1112 (600)	2
I-71-1593	6061	MD101	77.0	57.2	338 (170)	200	5-7	12.6	1112 (600)	2
169-4	6061	X8001	61.9	46.0	228 (109)	200	5-7	26.3	1050 (565)	3
169-5	6061	X8001	61.9	46.0	228 (109)	200	5-7	28.8	> 1050 (> 565)	3
169-11	6061	X8001	52.0	38.7	228 (109)	200	5-7	23.1	1000 (538)	3
169-12	6061	X8001	52.0	38.7	228 (109)	200	5-7	24.3	1050 (565)	3
169-19	6061	X8001	43.0	32.0	228 (109)	200	5-7	19.7	1050 (565)	3
169-36	6061	X8001	52.8	39.2	228 (109)	200	5-7	25.1	> 1050 (> 565)	3
169-37	6061	X8001	52.7	39.2	228 (109)	200	5-7	25.5	1000 (538)	3
169-38	6061	X8001	52.7	39.2	228 (109)	200	5-7	25.0	1000 (538)	3
169-39	6061	X8001	52.7	39.2	228 (109)	200	5-7	23.9	1050 (565)	3

TABLE 2A

UAL_x FUEL CORE BLISTER DATA

Reactor	Fuel Characteristics									
			Weight Percent							
Sample ID	Clad	Core	UAL_x	U	Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Blister Temp, °F (°C)	Ref
FNR	6061	5214	19.1	14.2	172 (78)	9.2	5-7	15.0		
MTR										
113-8	6061	6061	46.7	34.7	239 (115)	50	5-7	4.5	> 1100 (> 594)	1
113-9	6061	6061	46.7	34.7	239 (115)	50	5-7	5.7	> 1100 (> 594)	1
113-10	6061	6061	46.7	34.7	239 (115)	50	5-7	6.2	> 1100 (> 594)	1
113-11	6061	6061	46.7	34.7	239 (115)	50	5-7	7.2	> 1100 (> 594)	1
113-12	6061	6061	46.7	34.7	239 (115)	50	5-7	10.5	> 1100 (> 594)	1
113-13	6061	6061	46.7	34.7	239 (115)	50	5-7	9.2	1022 (550)	1
113-14	6061	6061	46.7	34.7	239 (115)	50	5-7	9.5	932 (500)	1
113-15	6061	6061	46.7	34.7	239 (115)	50	5-7	11.3	932 (500)	1
113-16	6061	6061	46.7	34.7	239 (115)	50	5-7	12.5	1067 (575)	1
113-17	6051	6061	46.7	34.7	239 (115)	50	5-7	20.3	932 (500)	1
FR2 (Kalsruhe, Germany)										
1-4	1100	1100	50	37.2	158 (70)	50	5-7	5.8	> 932 (> 500)	5
2-4	1100	1100	50	37.2	158 (70)	50	5-7	16.9	> 932 (> 500)	5
3-4	1100	1100	50	37.2	158 (70)	50	5-7	12.2	> 932 (> 500)	5
4-1	1100	1100	50	37.2	158 (70)	50	5-7	9.4	> 932 (> 500)	5
5-3	1100	1100	45.5	33.8	158 (70)	50	5-7	9.4	> 932 (> 500)	5
6-4	1100	1100	45.5	33.8	158 (70)	50	5-7	7.6	> 932 (> 500)	5
7-2	1100	1100	50	37.2	158 (70)	50	5-7	15.8	> 932 (> 500)	5
8-2	1100	1100	45.5	33.8	158 (70)	50	5-7	15.8	> 932 (> 500)	5
9-3	1100	1100	50	37.2	158 (70)	50	5-7	5.8	> 932 (> 500)	5
10-1	1100	1100	45.5	33.8	158 (70)	50	5-7	5.8	> 932 (> 500)	5
11-4	1100	1100	50	37.2	248 (120)	50	5-7	10.0	> 932 (> 500)	5
12-4	1100	1100	50	37.2	275 (135)	50	5-7	10.0	> 932 (> 500)	5

TABLE 2A

UAL_x FUEL CORE BLISTER DATA

Reactor	Fuel Characteristics									
			Weight Percent		Core Temp, °F (°C)	Operating Pressure PSIG	pH	Fission Density f/cc X 10^{20}	Blister Temp, °F (°C)	Ref
Sample ID	Clad	Core	UAL_x	U						
FNR	6061	5214	19.1	14.2	172 (78)	9.2	5-7	15.0		
FR2 (Kalsruhe, Germany)										
13-2	1100	1100	50	37.2	302 (150)	50	5-7	10.0	> 932 (> 500)	5
14-2	1100	1100	50	37.2	302 (150)	50	5-7	19.0	> 932 (> 500)	5
15-2	1100	1100	45.5	33.8	302 (150)	50	5-7	19.0	> 932 (> 500)	5
16-2	1100	1100	50	37.2	302 (150)	50	5-7	25.9	> 932 (> 500)	5
17-2	1100	1100	45.5	33.8	302 (150)	50	5-7	25.9	> 932 (> 500)	5
18-1	1100	1100	50	37.2	302 (150)	50	5-7	21.6	> 932 (> 500)	5
19-1	1100	1100	45.5	33.8	302 (150)	50	5-7	21.6	> 932 (> 500)	5
20-2	1100	1100	45.5	33.8	302 (150)	50	5-7	21.6	> 932 (> 500)	5

TABLE 2A

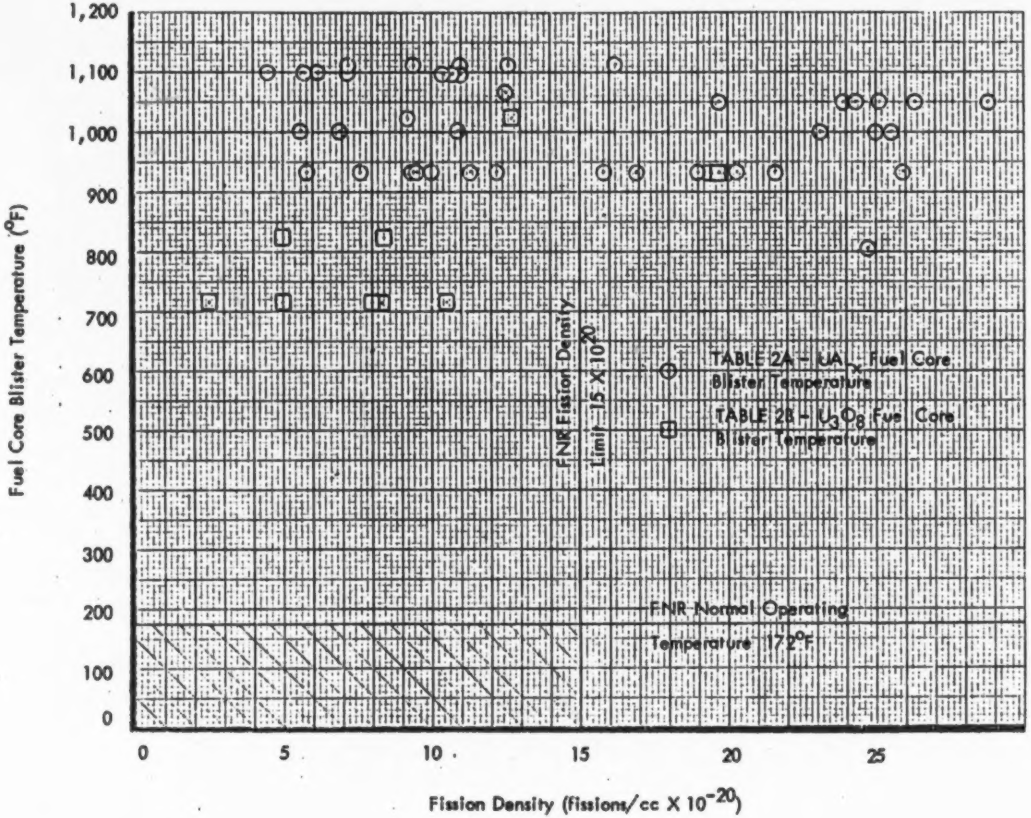
U_3O_8 FUEL CORE BLISTER DATA

Reactor	Fuel Characteristics									
			Weight Percent		Core	Operating		Fission	Blister	
Sample ID	Clad	Core	U_3O_8	U	Temp, °F (°C)	Pressure PSIG	pH	Density f/cc X 10^{20}	Temp, °F (°C)	Ref
FNR	6061	5214	16.8	14.2	172 (78)	9.2	5-7	15.0		
MTR										
1	6061	X8001	----	----	239 (115)	50	5-7	2.5	716 (380)	1
2	6061	X8001	----	----	239 (115)	50	5-7	5.0	716 (380)	1
3	6061	X8001	----	----	239 (115)	50	5-7	5.0	824 (440)	1
4	6061	X8001	----	----	239 (115)	50	5-7	8.0	716 (380)	1
5	6061	X8001	----	----	239 (115)	50	5-7	8.2	824 (440)	1
6	6061	X8001	----	----	239 (115)	50	5-7	8.3	716 (380)	1
7	6061	X8001	----	----	239 (115)	50	5-7	10.5	716 (380)	1
ETR										
68-1633	6061	PB-04*	49	41.4	419 (215)	200	5-7	12.7	1022 (550)	8
68-1638	6061	PB-04	49	41.4	428 (220)	200	5-7	12.7	1022 (550)	8
68-1643	6061	PB-04	49	41.4	410 (210)	200	5-7	12.7	1022 (550)	8
68-997	6061	PB-04	49	41.4	347 (175)	200	5-7	19.7	932 (500)	8
68-1605	6061	PB-04	49	41.4	329 (165)	200	5-7	19.9	932 (500)	8
68-1607	6061	PB-04	49	41.4	338 (170)	200	5-7	19.5	932 (500)	8

* Aluminum Powder Blends

FIGURE 2

FUEL CORE BLISTER TEMPERATURES



All of the available fuel blister data for UAL_x and U_3O_8 fuel which has been operated under conditions similar to those in the FNR indicate that UAL_x and U_3O_8 fuel can be safely used in the FNR without failure due to blistering and without reducing the safety margin.

6. FAILURE HISTORY

Table 3 provides a listing of reactor operating parameters for those reactors for which test data were provided in Table 1 and Table 2 and for the Ford Nuclear Reactor. Table 3 shows that the Advanced Test Reactor (ATR) routinely uses fuel with higher UAL_x loading than that proposed for FNR low enrichment uranium fuel. Similarly, the High Flux Isotope Reactor (HFIR) routinely uses fuel with U_3O_8 loadings equivalent to that proposed for the FNR.

The swelling and blistering data in Section 5 is for fuel cores with several aluminum alloys, but not 5214 alloy. The different core materials (powder blends, 1100, 6061, and X8001) show no significant effects on swelling and blistering characteristics. In addition, alloy 5214 is quite similar to 1100 as the list of constituents below indicates. Both essentially are pure aluminum powder.

	Constituents	1100	5214
Maximum:	Boron	—	0.001%
	Cadmium	—	0.002%
	Copper	0.20%	0.20%
	Iron	—	0.05%
	Lithium	—	0.008%
	Manganese	0.05%	
	Silicon + Iron	1.00%	0.25%
	Zinc	0.10%	0.10%
	Others	0.15%	—
Minimum:	Aluminum	99%	99.7 %

The failure history for the Advanced Test Reactor in Section 6.1 provides extensive operational data. Advanced Test Reactor fuel cores are 5214 aluminum.

6.1 Uranium Aluminide (UAL_x)

To date, the Advanced Test Reactor has operated over 89,000 UAL_x fuel plates up to the depletion limit of 2.3×10^{21} fissions/cc. In all of these fuel plates, only one (and this one was found to have thinly rolled clad) allowed fission product leakage into the ATR coolant. The plate was operated to depletion.

The thin clad was attributed to "dogboning" in the fuel core which has been eliminated by sloping the edges of the core ingot before rolling.

To date, twenty-one 93% enrichment aluminide fuel plates with 5214 aluminum cores have been operated to partial depletion in the Ford Nuclear Reactor. The peak fission density among these elements is 1.27×10^{20} fissions/cc. Inspections for fuel damage are not specifically performed, but the plates have shown no evidence and given no indication of swelling, blistering, warping, or cracking.

TABLE 3A

TRAINING, RESEARCH, AND TEST REACTOR OPERATING PARAMETERS

Parameter	Materials Testing Reactor (MTR)[1, 23]	Engineering Test Reactor (ETR)[1, 23]	Advanced Test Reactor (ATR)[1, 23]	High Flux Isotope Reactor (HFIR)[9, 23]	High Flux Beam Reactor (HFBR)[10, 23]
Year placed in service	1952	1956	1967	1965	1965
Thermal power (MW)	40	175	40	100	40
Thermal power density (MW/l)	0.75	1.2	2.8	1.5	0.5
Fuel element meat volume (cc)	365	550	798	3475	870
U-235 per element (gm)	200	400	975	2600	315
U-235 burnup (%)	---	25	25	30.6	34
Peak fission density (fiss/cc)	---	1.8×10^{21}	2.3×10^{21}	1.9×10^{21}	1.24×10^{21}
Fuel element surface area (ft^2)	15	23	34	147	36
Heat flux (BTU/ft^2-hr)	3.5×10^5	5×10^5	4×10^5	2.5×10^5	3.8×10^5
Coolant flow rate (gpm)	24,000	44,000	16,000	17,000	16,6000
Fuel element materials:					
Cladding	1100 Al	1100 Al	6061 Al	6061 Al	6061 Al
Core	1100 Al	5214 Al	5214 Al	1100 Al	1100 Al
Core Fissile Compound (Weight %)	UAL_x 46.0	UAL_x 40.6	UAL_x 45.1 - 60.8	U_3O_8 25.6	U_3O_8 40.6
Core Uranium (Weight %)	34.2	30.2	33.5 - 45.2	21.6	34.3
Fuel Plate thickness (in)					
Clad	0.015	0.015	0.015	0.010	0.014
Core	0.020	0.020	0.020	0.030	0.023
Overall	0.050	0.050	0.050	0.050	0.051

TABLE 3B

FORD NUCLEAR REACTOR OPERATING PARAMETERS

Parameter	High Enrichment Fuel Uranium Aluminum Alloy (U-Al)	 Uranium Aluminide (UAL$_x$)[23]	Proposed Low Enrichment Fuel Uranium Aluminide (UAL$_x$)	 Uranium Oxide (U_3O_8)
Year placed in service	1958	1978	1980	Undetermined
Thermal power (MW)	2	2	2	2
Thermal power density (MW/l)	.025	.025	.025	.025
Fuel element meat volume (cc)	354	335	502	502
U-235 per element (gm)	140	140	167	167
U-235 burnup (%)	35	35	50	50
Peak fission density (fiss/cc)	1.5×10^{20}	1.5×10^{20}	2.6×10^{20}	2.6×10^{20}
Fuel element surface area (ft^2)	15	15	15	15
Heat flux (BTU/ft^2-hr)	3.68×10^4	3.68×10^4	3.68×10^4	3.68×10^4
Coolant flow rate (gpm)	980	980	980	980
Fuel element materials:				
Cladding	6061 Al	6061 Al	6061 Al	6061 Al
Core	1100 Al	5214 Al	5214 Al	1100 Al
Core Fissile Compound (Weight %)	Not Applicable	19.1	56.5	49.6
Core Uranium (Weight %)	14.2	14.2	42.0	42.0
Fuel plate thickness (in)				
Clad	.020	.015	.015	.015
Core	.020	.020	.030	.030
Overall	.060	.050	.060	.060
Coolant flow channel thickness (in)	.117	.125	.117	.117

6.2 Uranium Oxide (U_3O_8)

To date, the High Flux Isotope Reactor has operated over 76,000 U_3O_8 fuel plates up to the depletion limit 1.9 X 10^{21} fissions/cc with no failures. On two occasions, fuel plates developed suspected fission product leaks. In one case, the apparent leak was so insignificant that the element was operated to depletion. In the second case, the element was removed after 1500 MWD.[9] Destructive tests showed no evidence of blisters, cladding separation, matrix cracking, or any defects indicative of incipient failure.

7. FUEL SPECIFICATIONS

7.1 Uranium Aluminide (UAL_x)

FNR fuel specifications have been developed in co-operation with the ATR staff at the Idaho National Engineering Laboratory and Atomics International (AI), the ATR fuel manufacturer. The UAL_x specification is identical to that specified by ATR. The present ATR fission density limit is 23 X 10^{20} fissions/cc.

The fuel swelling and blister data in the references and tables often refer to aluminide as UAL_3. The early intermetallic fuel development work in Idaho was for the fabrication and testing of UAL_3 material and so the early designation was UAL_3. During this early fuel testing work, it was recognized that aluminide was not purely UAL_3. In 1966, UAL_3 was identified as the major crystalline component with UAL_2 and UAL_4 present.[11] Current ATR fuel powder specifications require the UAL_3 content to be at least 50%.

The FNR fuel powder specification calls for uranium aluminide powder containing at least 50% UAL_3.

7.2 Uranium Oxide (U_3O_8)

U_3O_8 fuel specifications will be developed in co-operation with Oak Ridge National Laboratory (ORNL) and Brookhaven National Laboratory (BNL) should U_3O_8 fuel be used in the FNR.

8. HEAT TRANSFER CHARACTERISTICS

The proposed LEU fuel heat transfer characteristics will be essentially identical to those of alloy fuel which has been used in the FNR core since 1957 and still comprises the majority of the fuel elements in the core. Overall element dimensions, fuel plate dimensions, and coolant flow channel width and thickness are unchanged.

Peak fuel temperature in the hottest FNR fuel plate is calculated to be 172°F. The margin of operational safety will not be changed by the use of LEU fuel.

9. CORE PHYSICS

The core physics analysis of the proposed LEU fuel reflects two basic differences from the HEU fuel currently used in the FNR core: (1) the fuel loading will be increased from 140 grams to 167.3 grams of ^{235}U per 18-plate element to compensate for increased neutron absorption in ^{238}U and spectrum hardening, and (2) the fuel meat thickness will be increased from .020 inches to .030 inches, with clad thickness decreased from .020 to .015 inches, to maintain the same total fuel plate thickness while allowing for the larger amount of ^{238}U. The proposed LEU fuel specifications are selected so that the excess reactivity of a batch fresh core configuration is the same for both the current HEU fuel and the proposed LEU fuel.

The core physics analysis includes examination of the effect of LEU fuel on core power distribution, in-core and ex-core flux distribution, cycle length and operating characteristics, core excess reactivity and shutdown margin.

9.1 Description of Calculational Methods

9.1.1 Computer Codes Used for Core Physics Analysis

All analysis was performed with the standard, well-verified production codes LEOPARD[12], EPRI-HAMMER[13], 2DB[14], ANISN[15], TWOTRAN[16], and VENTURE[17]. Brief descriptions of code capabilities are:

1) LEOPARD - a zero-dimensional unit-cell code using the MUFT/SOFOCATE scheme (54 fast and 172 thermal groups); has depletion capability; cross-section library consists of an early industrial data set.

2) EPRI-HAMMER - a one-dimensional integral transport theory code using 54 fast and 30 thermal groups; cross-section library constructed from ENDF/B-IV data.

3) 2DB - a two-dimensional multi-group diffusion theory code with depletion capability.

4) ANISN - a one-dimensional discrete ordinates transport theory code.

5) TWOTRAN-II - a two-dimensional discrete ordinates transport theory code.

6) VENTURE - a three-dimensional multi-group diffusion theory code

9.1.2 Code Modifications

The LEOPARD code originally performed a spectrum calculation for lattices consisting of cylindrical fuel rods. The code was modified to allow slab geometry and separate few-group edits for both lattice and non-lattice regions. The principal modification was in the calculation of thermal disadvantage factors by the ABH method for slab geometry[18].

The modified LEOPARD code compares satisfactorily with the EPRI-HAMMER code, an accurate, well-verified code used in the analysis of benchmark critical experiments.[19] A typical comparison of k_∞ and two-group parameters in Table 4 shows that despite the many engineering approximations in the LEOPARD code, it compares quite well with the more accurate HAMMER code. Differences in few-group constants are due primarily to differences in the cross-section libraries - HAMMER uses ENDF/B-IV data while LEOPARD uses an early industrial data set.

The 2DB code has been modified to allow a macroscopic depletion capability via interpolation of macroscopic cross sections as a function of depletion. In addition, the isotopic balance equations for xenon and iodine have been included to allow the correct xenon levels within the core as a function of position and time (and macroscopic absorption cross sections are appropriately modified). Other modifications to 2DB have been aimed at automating data handling (e.g., the link with LEOPARD to produce macroscopic cross sections as a function of depletion) and improving fuel shuffling and edit capabilities.

9.1.3 Basic Calculation Method

The LEOPARD and 2DB codes were used for routine calculations of core reactivity, depletion effects, and power and flux distributions. Special methods for control rods and core leakage flux are described in subsequent sections. For both HEU and the proposed LEU fuel, the following scheme was followed:

1) The LEOPARD code was used to generate few-group cross sections. For most applications, two energy groups (fast and thermal) were used, although four energy groups were chosen for several detailed calculations.

   The geometry chosen was a unit cell in slab geometry consisting of a lattice region and a non-lattice or extra region. The lattice region was composed of fuel meat, clad and water channel. For regular assemblies, the extra region consisted of the side plates, non-active portions of fuel plates, and inter-assembly water gaps, which were homogenized on a volume basis. For special* fuel assemblies, the central water hole was also included in the extra region.

   Few-group macroscopic cross-section sets were generated as functions of depletion for the lattice and non-lattice regions and the total assembly.

   For the water reflector and heavy water tank, the extra region was chosen as H_2O or D_2O with a .25% H_2O content with a volume fraction

---

*Special is used in this section to designate control assemblies.

Table 4. Comparison of LEOPARD and HAMMER Results for MTR-type Fuel

	93% Alloy		19.5% UAl_x	
	LEOPARD	HAMMER	LEOPARD	HAMMER
k_∞	1.5477	1.5500	1.5150	1.5116
ϕ_1/ϕ_2	2.41	2.40	2.76	2.75
Age	51.5	49.9	49.1	47.5
D_1	1.434	1.372	1.424	1.360
Σ_{a1}	0.00204	0.00182	0.00358	0.00344
Σ_{r1}	0.0258	0.0257	0.0254	0.0253
$\nu\Sigma_{f1}$	0.00206	0.00223	0.00256	0.00274
D_2	0.284	0.272	0.280	0.269
Σ_{a2}	0.0597	0.0594	0.0676	0.0668
$\nu\Sigma_{f2}$	0.0948	0.0935	0.110	0.108

arbitrarily set equal to that of the lattice region. The extra region few-group cross sections obtained in this manner were used for the reflector and heavy water tank in the subsequent global calculation.

2) Global diffusion theory calculations were performed with the 2DB code. Three spatial mesh descriptions were used in x-y geometry: a homogeneous description, with a 2x2 mesh per assembly, was used for survey calculations, equilibrium core studies, and cycle length studies. A discrete representation, using a 6x6 mesh per assembly with the lattice and non-lattice portions of an assembly explicitly represented, was used for detailed analysis of power and flux distributions, temperature coefficient, and control rod reactivity worth. A discrete representation with a 12x12 mesh per assembly was used for verifying the adequacy of the 2x2 and 6x6 representations, and for comparison with the measured flux distributions.

   Depletion was accounted for on the assembly level by interpolating macroscopic cross sections as a function of depletion (MWD/MT) for the particular assembly in question. The fuel shuffling capability in the 2DB code allowed actual FNR operation to be simulated. The axial buckling term for the 2DB code used to approximate transverse leakage was based on the active core height with a reflector savings correction.

9.1.4 Control Rod Worth Calculations

FNR control (shim) rods are boron stainless steel containing 1.5 w/o natural boron. They are essentially black to thermal neutrons and cause a drastic thermal flux depression when inserted. The presence of such strong localized absorbers necessitates the use of transport theory codes to adequately describe the large flux gradients. However, in a small high leakage core like the FNR, control rod effects are not strictly local; therefore whole core calculations are needed, but are prohibitively expensive for transport theory codes. To accurately treat both local and global effects, transport theory codes were used for assembly level calculations to develop effective diffusion theory constants for global calculations. The method developed is a variation of the "NGD blackness method"[20] and has proved quite accurate.

Few-group constants for the control rod and surrounding water were obtained from the EPRI-HAMMER code for a cylindricized special assembly. Due to the strong spectral/spatial coupling in the rod it was necessary to obtain few-group cross sections for three control rod regions - a surface layer .1 cm thick, a second layer .3 cm thick, and the central region. Since few thermal neutrons reach the central region, the control rod perimeter, rather than volume, was preserved in the geometric representation. Few-group constants for the special element lattice and side regions were obtained from the EPRI-HAMMER calculations for one half of a special element in slab geometry.

To accurately model the local effects of an inserted rod, the two-dimensional transport code TWOTRAN was used in fine-mesh calculations for a special assembly surrounded on all sides by one half of a regular assembly. Three regions of the rod and the surrounding water were explicitly represented, while the surrounding lattice regions were homogenized.

To develop effective few-group diffusion theory constants for use in global 2DB calculations, the 2DB code was used for the same geometry as in TWOTRAN calculations, except that the control rod and surrounding water were homogenized. Both fast and thermal absorption cross sections were varied until the 2DB calculation yielded the same relative absorption in the control region as the TWOTRAN result in each group. The resulting few-group constants for the control region were then used in global 2DB calculations. Although the flux distribution within the control region differs from the transport theory results, we believe the relative absorption in the control region and the flux in the surrounding fuel is accurately predicted in this scheme.

Control rod worth was then determined by comparing global 2DB calculations for the 6x6 mesh/assembly description with and without control rod inserted.

9.1.5 Calculational Methods for Temperature Coefficient of Reactivity and Xenon Reactivity Worth

Calculation of the temperature coefficient of reactivity and of reactivity worth of xenon poisoning was performed with global 2DB calculations with a 6x6 mesh/assembly description. The two-group cross sections for these 2DB cases were obtained from unit-cell calculations with the LEOPARD or the EPRI-HAMMER code, essentially following the basic scheme outlined in Section 9.1.3.

9.1.6 Equilibrium Core Model

Although the FNR core configuration and fuel shuffling pattern are, in practice, determined by operational requirements, an equilibrium core model was developed to allow for meaningful comparison of operating characteristics for the HEU and the proposed LEU cores. Our equilibrium core model essentially simulates a typical FNR shuffling pattern. Fresh fuel assemblies are placed near the control assemblies at the core center and are moved outward as they deplete. This pattern maximizes the control rod reactivity worth. The shuffling pattern was varied until the fuel depletion per cycle at each assembly location obtained with global 2DB calculations closely matched that of the average FNR depletion at each location. The 2DB calculations performed over many cycles led to an equilibrium core model which, although not unique, is a realistic representation of the typical FNR operating cycle.

9.1.7 Ex-core Calculations

The ANISN and 2DB codes were used to calculate flux distributions in the H_2O and D_2O reflectors. Cross sections for the ANISN calculation were taken from the 100 group DLC -2 library and collapsed (with ANISN) to few groups. For 2DB calculations cross sections were generated by the LEOPARD code as explained in Section 9.1.3.

9.2 Comparison of Calculated and Experimental Results

The adequacy of the methods used for calculating core physics parameters for FNR core configurations has been established through comparing the calculated results with the data from several research and test reactors. In these verification efforts the calculated thermal flux and power distributions were compared with the experimental data obtained at the Bulk Shielding Reactor (BSR)[21], the High Flux Beam Reactor (HFBR)[22], and the FNR. The data for the BSR and HFBR cores were obtained at core configurations with MTR-type fuel elements similar to the FNR configurations.

9.2.1 Flux and Power Distributions

The measured thermal flux distributions and the core multiplication constants for the BSR loading 33 provide well documented experimental data[21] for a fresh critical core. The neutron flux distribution for this core was determined with x-y 2DB calculations utilizing a 6x6 and a 12x12 mesh per fuel assembly. Table 5 compares calculated and experimental results for the BSR and representative FNR configurations. Here the high neutron leakage causes the effective multiplication factor of the reactor to be sensitive to the input buckling value used to represent the leakage in the missing transverse direction. These calculations used an axial buckling of 2×10^{-3} cm^{-2}, which includes a calculated reflector savings.

Calculated results have been compared with the experimental data for a number of FNR core configurations. The assembly average power distribution in the Cycle 67 core was measured on March 17, 1971, with the core loading pattern presented in Figure 3. The power distribution was measured by thermocouples, with the coolant inlet temperature for each element measured inside the fuel element boxes and above the fuel plates, and the outlet temperature measured below the fuel plates in the element cone. From the assembly inlet

Case	Mesh/Group Structure	Core Reactivity		RMS Deviation[1] (thermal flux or assembly power)
		Measured	Calculated	
A (BSR #33)	6x6/2 group	1.006	1.009	11.3%[3]
	6x6/4 group	1.006	1.004	10.1%[3]
	12x12/2 group	1.006	1.012	7.8%[3]
B (FNR #67)	6x6/2 group	1.001	1.007[2]	9.3%[4]
C (FNR 1977 critical)	2x2/2 group	1.000	1.000[2]	---
	6x6/2 group	1.000	1.000[2]	---

Notes

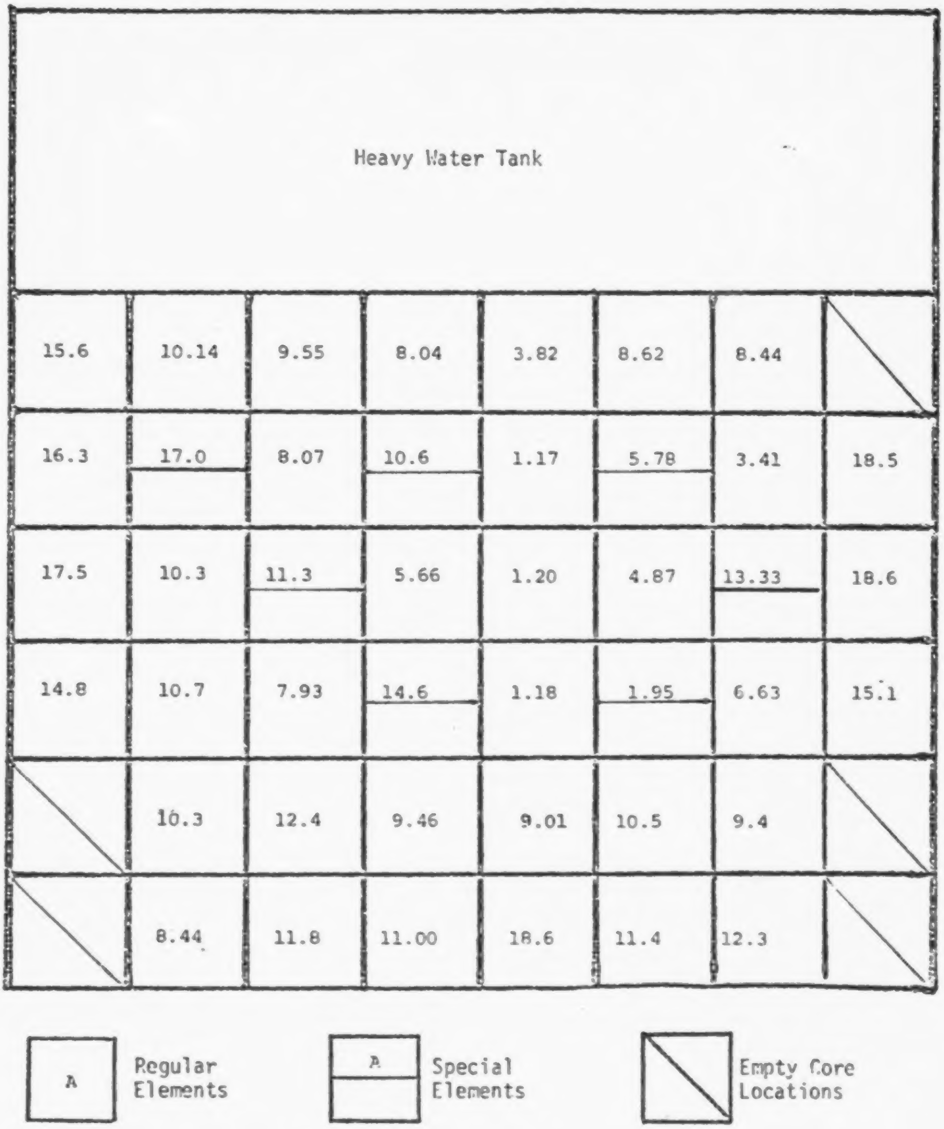
1. RMS deviation = $\sqrt{\frac{1}{N-1} \sum_{i} \left(\frac{calc - exp}{exp}\right)_{i}^{2}}$

2. Corrected for measured xenon worth

3. Thermal flux deviation at 17 locations

4. Assembly power fraction deviation at 42 locations

Table 5. Experimental and Calculated Results for Several Reactor Configurations.


Heavy Water Tank
A
Regular Elements
A
Special Elements
Empty Core Locations

15.6	10.14	9.55	8.04	3.82	8.62	8.44	⧅
16.3	17.0	8.07	10.6	1.17	5.78	3.41	18.5
17.5	10.3	11.3	5.66	1.20	4.87	13.33	18.6
14.8	10.7	7.93	14.6	1.18	1.95	6.63	15.1
⧅	10.3	12.4	9.46	9.01	10.5	9.4	⧅
⧅	8.44	11.8	11.00	18.6	11.4	12.3	⧅

A: Assembly Burnup (MWD/assembly)

Figure 3. Fuel Burnup Distribution for FNR Cycle 67

and outlet temperatures, the power for each regular fuel element was calculated assuming equal coolant flow rate through each element. The assembly-average power distribution calculated by the 2DB code and the measured power distribution for the Cycle 67 core are presented in Figure 4. In this calculation the 2DB code predicted the core power distribution to within an rms deviation of 9.3%, as shown in Table 5.

The thermal flux distribution in the FNR Cycle 163B core was determined through flux maps obtained with a self-powered rhodium detector. The measurements were taken at the horizontal midplane of the core at the center of each regular fuel element. The core configuration for this cycle is shown in Figure 5, and a comparison of the calculated and measured thermal flux distributions is given in Figure 6. The calculated flux distribution shows good agreement with the measured distribution, with an rms deviation of 5.1%. Comparisons made for other fuel cycles show similar agreement between the measured and calculated results, with rms deviations in the range of 5 ~ 8%.

9.2.2 Ex-core Flux Distributions

Initial calculations to predict leakage neutron flux in the FNR D_2O tank concentrated on determining the accuracy of diffusion theory vs. transport theory calculations and on identifying critical parameters. Transport theory calculations performed in one-dimensional slab geometry with the ANISN code[15], and diffusion theory calculations performed with one- and two-dimensional codes were compared with experimental measurements for the FNR, BSR, and HFBR. The results indicate that because of the large thermal diffusion length in D_2O, diffusion theory can accurately predict the thermal flux distribution for considerable distances into heavy water. The calculations for D_2O reflectors were sensitive to the transverse buckling due to the small D_2O macroscopic absorption cross-section. In a 2DB model of the HFBR with R-Z geometry, diffusion theory accurately simulated the thermal flux profile[22] at distances of .6-.8 meters into the D_2O reflector.

9.2.3 Control Rod Reactivity Worth

Control rod reactivity worth calculations were performed for the A, B, and C shim rods for FNR Cycle 67. The method for obtaining the rod worths was identical to that discussed in Sec. 9.1.4 except that the depletion of the fuel in the special fuel elements had to be accounted for. Accordingly, isotopic number densities for each of the special fuel element lattice regions were taken from a LEOPARD depletion calculation for a special element at the corresponding burnup points. These number densities were then used in place of BOL number densities, and the sequence of HAMMER calculations described in Sec. 9.1.4 was repeated. Full-core 6x6 2DB calculations were then

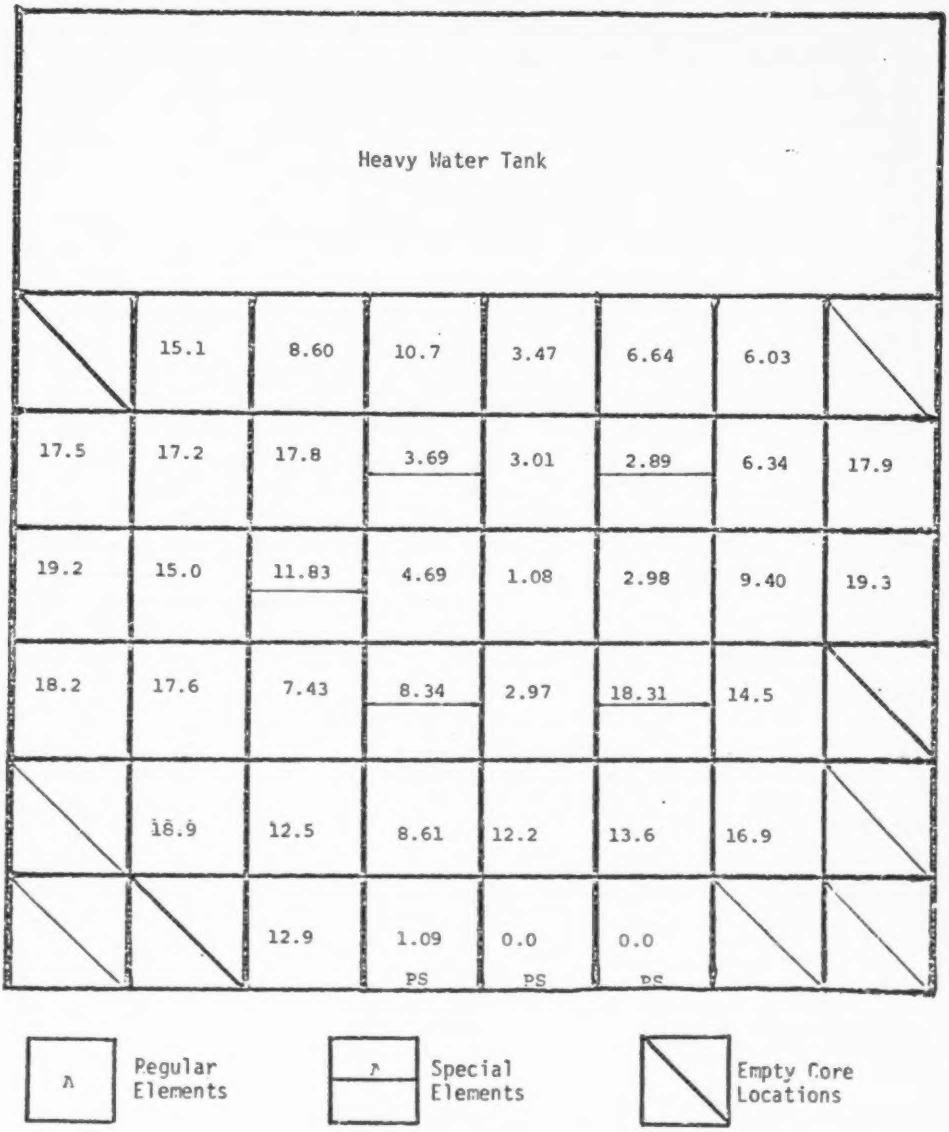
Heavy Water Tank

1.46 1.42	2.25 2.06	2.81 2.53	3.43 2.89	3.13 2.94	2.58 2.60	1.91 2.12	╲
1.80 1.76	1.26 1.28	3.73 3.46	2.06 2.02	4.12 4.00	1.83 1.97	2.32 2.76	1.41 1.72
1.93 1.82	3.14 2.85	1.96 1.95	4.64 4.17	3.69 4.08	3.75 3.77	1.26 1.49	1.66 1.82
1.95 1.83	2.66 2.55	3.50 3.39	1.74 1.90	3.86 4.26	1.94 2.07	2.30 2.71	1.58 1.77
╲	2.30 2.12	2.76 2.55	2.96 3.09		2.63 2.67	2.05 2.09	╲
╲	1.39 1.46	2.06 1.83	1.07 .98	2.12 2.13	1.80 1.71	1.25 1.42	╲

A B	Regular Elements	A B	Special Elements	╲	Empty Core Locations

A: Assembly Power (%), Measured
B: Assembly Power (%), Calculated
rms deviation = 9.3 %

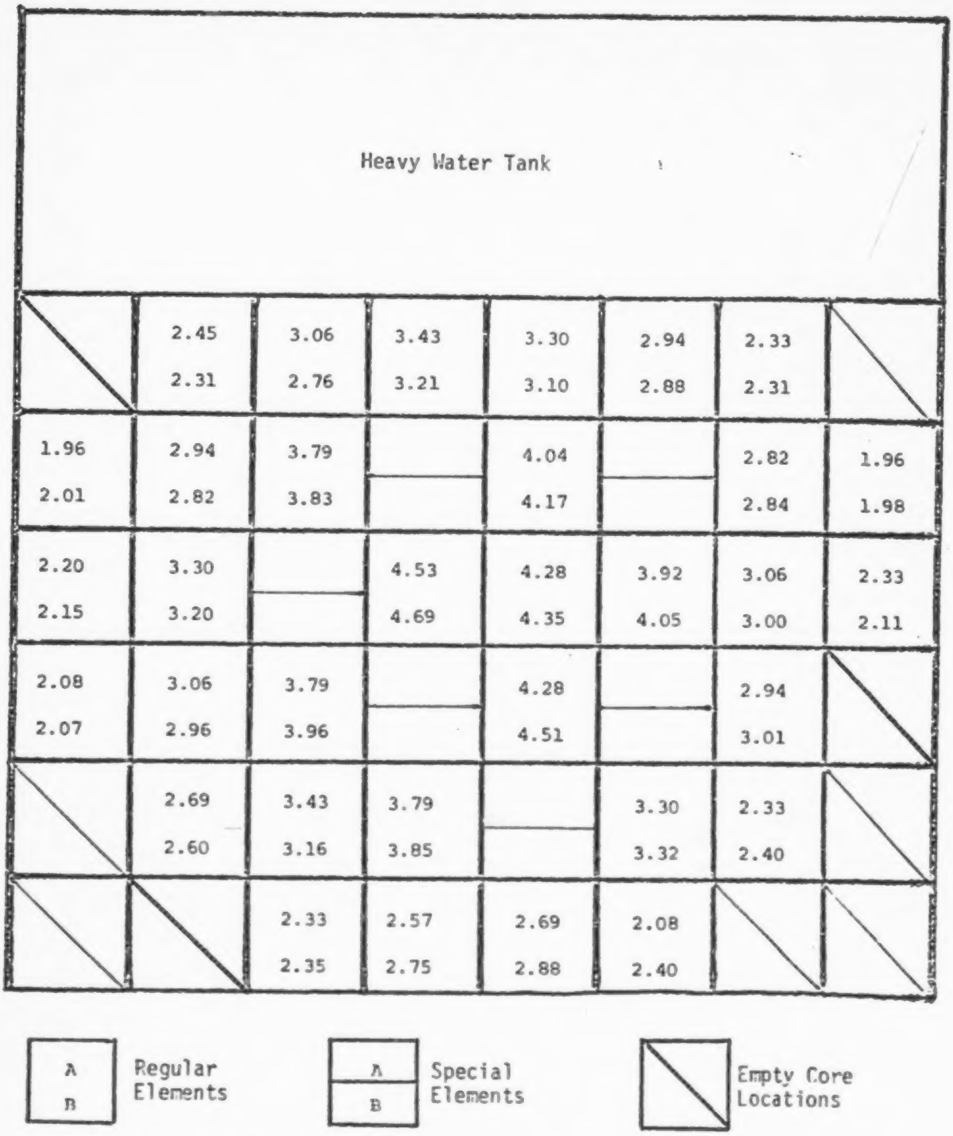
Figure 4. Experimental and Calculated Power Distributions for FNR Cycle 67


Heavy Water Tank
A
Regular Elements
A
Special Elements
Empty Core Locations

	15.1	8.60	10.7	3.47	6.64	6.03	
17.5	17.2	17.8	3.69	3.01	2.89	6.34	17.9
19.2	15.0	11.83	4.69	1.08	2.98	9.40	19.3
18.2	17.6	7.43	8.34	2.97	18.31	14.5	
	18.9	12.5	8.61	12.2	13.6	16.9	
		12.9	1.09 PS	0.0 PS	0.0 PS		

A: Assembly Burnup (MWD/assembly)
PS: Designates Penn State Fuel Elements

Figure 5. Fuel Burnup Distribution for FNR·Cycle 163D


Heavy Water Tank
A
B
Regular Elements
A
B
Special Elements
Empty Core Locations

╲	2.45 2.31	3.06 2.76	3.43 3.21	3.30 3.10	2.94 2.88	2.33 2.31	╲
1.96 2.01	2.94 2.82	3.79 3.83		4.04 4.17		2.82 2.84	1.96 1.98
2.20 2.15	3.30 3.20		4.53 4.69	4.28 4.35	3.92 4.05	3.06 3.00	2.33 2.11
2.08 2.07	3.06 2.96	3.79 3.96		4.28 4.51		2.94 3.01	╲
╲	2.69 2.60	3.43 3.16	3.79 3.85		3.30 3.32	2.33 2.40	╲
╲	╲	2.33 2.35	2.57 2.75	2.69 2.88	2.08 2.40	╲	╲

A: Assembly-Average Thermal Flux, Measured
B: Assembly-Average Thermal Flux, Calculated] rms deviation=5.1%

Figure 6. Experimental and Calculated Thermal Flux Distributions for FNR Cycle 163B

performed with all rods out and then separate runs were made with each of the three rods inserted. The calculated and measured rod worths compared as follows:

	Rod worth (% Δk/k)	
Shim rod	Measured	Calculated
A	2.22	2.20
B	2.11	2.11
C	1.72	1.73
Total rod worth	6.05	6.04

The agreement is excellent and provides verification of the methods for computing control rod worth in small, high-leakage cores. While there still exist some uncertainties in the actual measured rod worth, the close agreement indicates that the basic approach is valid.

9.3 Comparison of HEU and Proposed LEU Fueled Cores

To provide a meaningful and comprehensive comparison of HEU and proposed LEU fuels, it is necessary to account for both the intrinsic fuel properties and the FNR operating conditions. For the purpose of comparing core phyiscs parameters, two core configurations were analyzed for both fuels. The first configuration corresponds to a batch core consisting of fresh fuel assemblies, while the second configuration is based on an equilibrium core. The batch core configuration allows a comparison of undepleted HEU and LEU fuels, while the equilibrium core allows comparison of depletion characteristics and shutdown margin for conditions approximating typical FNR operation.

The following sections include a description of the model core configurations and a comparison of core physics parameters.

9.3.1 Description of Batch and Equilibrium Core Models

The batch core model consists of 31 fresh fuel assemblies, with four special assemblies at control rod locations. The configuration is symmetric about the north/south midplane and was analyzed using half-core calculations with a 6x6 mesh/assembly. Figure 7 illustrates this configuration.

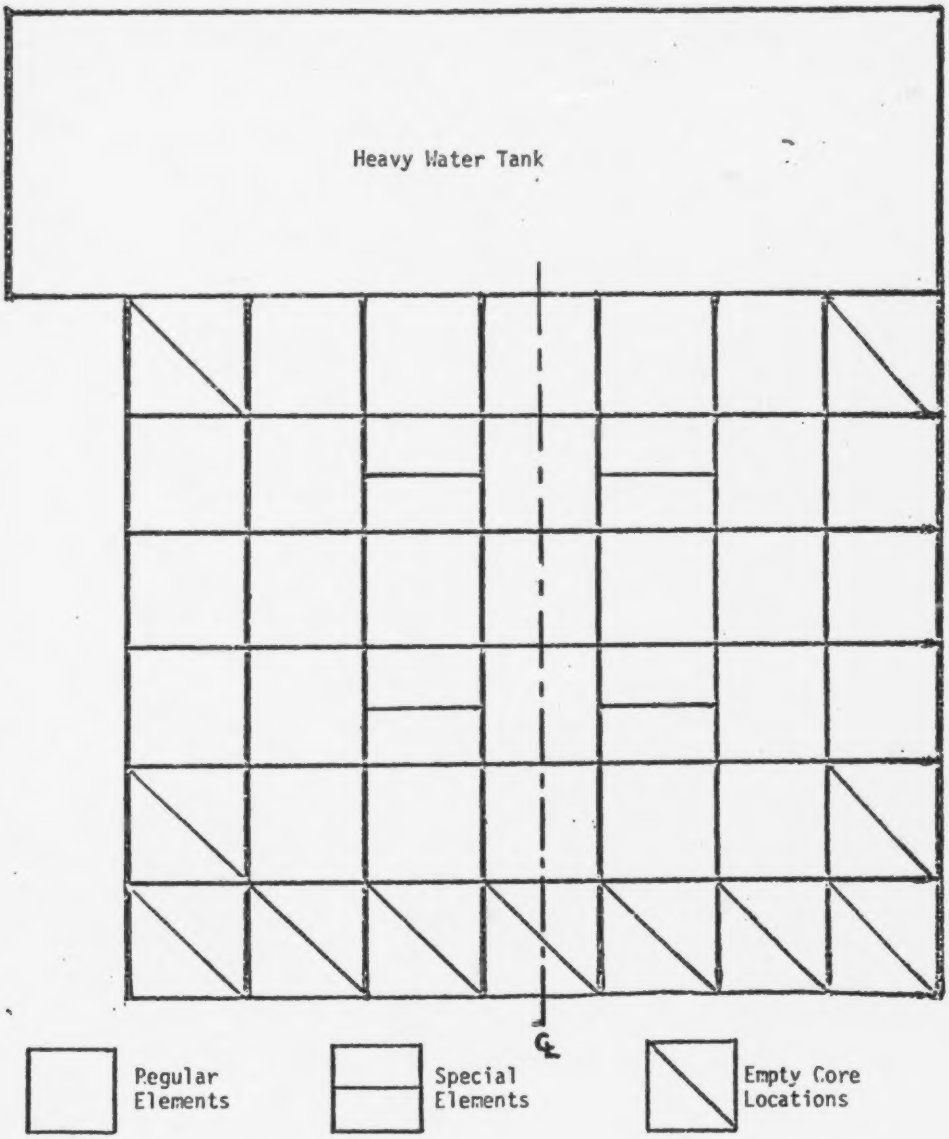

Heavy Water Tank
℄
Regular Elements
Special Elements
Empty Core Locations

Figure 7. Batch Core Configuration

The equilibrium core configuration shown in Figure 8 essentially simulates a typical FNR shuffling pattern, and is chosen so that the core loading and shuffling patterns repeat every sixth cycle. The core configuration consists of 39 fuel elements including six special fuel elements. The important criteria for choosing the core loading pattern are:

1. Fresh fuel elements are loaded into the central region of the core. This maximizes control rod worth and helps maintain the required shutdown margin. The fuel elements are moved outward in an in/out shuffling scheme as they deplete.

2. The fuel elements are loaded so as to equalize the worths of the three shim rods. Because the B and C Rods tend to be less reactive, the reactivity worth of these shim rods is increased by loading relatively fresh fuel into the vicinity of B and C Rods. In contrast, more depleted fuel is loaded near the A Rod.

With these core loading criteria, an equilibrium core burnup distribution is obtained with 2DB calculations, which repeats cyclically over a given time period. The fuel element shuffling pattern for the equilibrium core divides the 33 regular fuel element locations into eight loading zones as shown in Figure 8. Each regular element loading zone corresponds to core locations having nearly equal fuel burnup, although not necessarily equal burnup rates. New fuel is loaded into Zone 1 and depleted fuel is discharged from Zone 8. At the start of each cycle, one new element is loaded into Zone 1, and the element in Zone 1 is moved to Zone 2. Another element is moved from Zone 2 to 3, and continuing to Zone 8, with a depleted element being discharged from Zone 8. Because the core loading zones have a maximum of six elements, the core burnup distribution repeats every sixth cycle. The eight-zone shuffling pattern for the regular elements is shown in Table 6.

The shuffling pattern for the special fuel elements is somewhat different since there are six special element locations. A new special element is added and a depleted element is discharged only every sixth cycle. With this shuffling pattern a new special element is placed in Special-Zone 1 at the start of cycle 1. The element removed from Special-Zone 1 is placed in ex-core storage for one cycle and then placed in Special-Zone 2 at the start of cycle 2. The element from Special-Zone 2 is moved to storage before being placed into Special-Zone 3 at the start of cycle 3. The sequence continues until the start of cycle 6 when the element from storage is placed into Special-Zone 6 and a depleted special element is discharged from the core. This shuffling pattern for special elements is shown in Table 7 .

While the reactivity decrease and core power distribution are nearly constant over each equilibrium cycle, the burnup distribution will repeat only every sixth cycle or over one macro-cycle. Any core para-

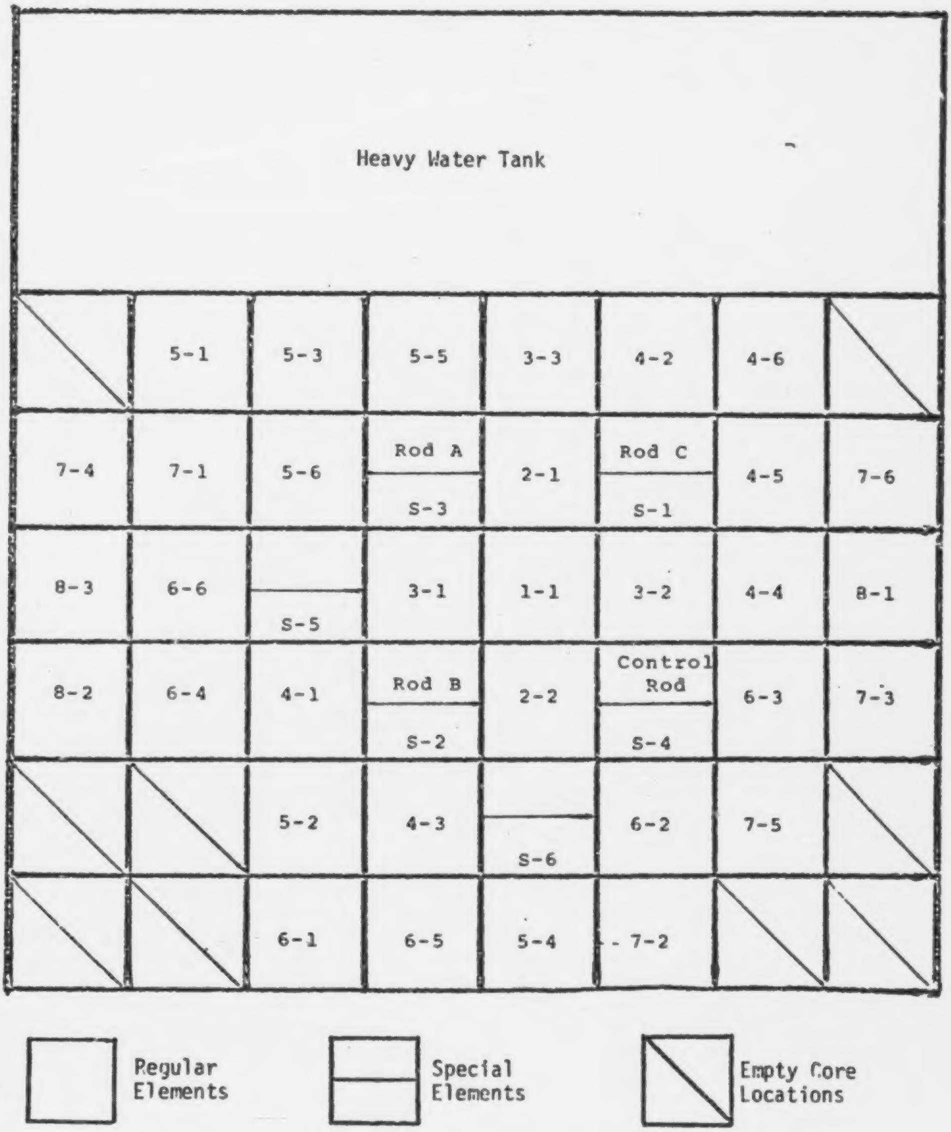

Heavy Water Tank
5-1
5-3
5-5
3-3
4-2
4-6
7-4
7-1
5-6
Rod A
S-3
2-1
Rod C
S-1
4-5
7-6
8-3
6-6
S-5
3-1
1-1
3-2
4-4
8-1
8-2
6-4
4-1
Rod B
S-2
2-2
Control Rod
S-4
6-3
7-3
5-2
4-3
S-6
6-2
7-5
6-1
6-5
5-4
7-2
Regular Elements
Special Elements
Empty Core Locations

Figure 8. Equilibrium Core Loading Pattern

Table 6

Regular Fuel Element Shuffling Scheme

Equilibrium Core Configuration
with 6 Cycles/Macro-cycle

Cycle	New Fuel	Core Loading Zone							
		1	2	3	4	5	6	7	8
1	→	1-1 →	2-1 →	3-1 →	4-1 →	5-1 →	6-1 →	7-1 →	8-1 →
2	→	1-1 →	2-2 →	3-2 →	4-2 →	5-2 →	6-2 →	7-2 →	8-2 →
3	→	1-1 →	2-1 →	3-3 →	4-3 →	5-3 →	6-3 →	7-3 →	8-3 →
4	→	1-1 →	2-2 →	3-1 →	4-4 →	5-4 →	6-4 →	7-4 →	8-1 →
5	→	1-1 →	2-1 →	3-2 →	4-5 →	5-5 →	6-5 →	7-5 →	8-2 →
6	→	1-1 →	2-2 →	3-3 →	4-6 →	5-6 →	6-6 →	7-6 →	8-3 →

Discharge

Table 7

Special Fuel Element Shuffling Scheme

Equilibrium Core Configuration
with 6 Cycles/Macro-cycle

Cycle	Storage		Core Loading Zone		Storage
1	New fuel	→	S-1	→	X_1
2	X_1	→	S-2	→	X_2
3	X_2	→	S-3	→	X_3
4	X_3	→	S-4	→	X_4
5	X_4	→	S-5	→	X_5
6	X_5	→	S-6	→	Discharge

meter will be exactly the same at a given time into any macro-cycle.

To verify the practicability of the equilibrium cycle, Table 8 presents a comparison of the calculated equilibrium core parameters and actual core parameters based on the FNR operating experience during the past year. These comparisons indicate that the proposed equilibrium cycle represents a reasonably practical configuration, which may be used to compare the characteristics of the LEU and HEU designs for typical FNR operating conditions.

9.3.2 Comparison of Core Physics Parameters for HEU and Proposed LEU Fueled Cores

The major physics parameters which have been analyzed include the power defect of reactivity, xenon reactivity worth, control (shim) rod reactivity worth, cycle length, and shutdown margin. Differences in these parameters, as computed for the two model core configurations should provide a reasonable estimate of any effects of LEU fuel on FNR safety margins. These differences are compared for several equilibrium cores with differing cycle length and the batch core.

9.3.2.1 Temperature Coefficient of Reactivity and Power Defect Comparison

The isothermal temperature coefficient of reactivity was computed for the batch core model to be -8.4 pcm/°F for the HEU fuel and -12.6 pcm/°F for the LEU fuel. The large increase is due almost exclusively to fuel Doppler effects. For the HEU fuel, fuel Doppler effects are negligible due to the small amount of ^{238}U present. For the LEU fuel, the large amount of ^{238}U increases resonance absorptions in ^{238}U, resulting in much larger sensitivity to fuel temperature. The principal contribution to temperature coefficient of reactivity for both the HEU and LEU configurations is the effect of the reduction in moderator density on leakage and moderation.

The power defect of reactivity represents the total of all reactivity effects induced by taking the reactor from a cold zero-power condition to normal operating conditions. Due to the spatially nonuniform temperature and density changes involved, the power defect cannot be predicted solely on the basis of an isothermal temperature coefficient. Since the increased fuel Doppler effect is, however, the principal difference in the temperature effects between the HEU and the LEU designs, the change in power defect of reactivity is estimated in the present analysis on the basis of calculated temperature coefficients. Based on an average core temperature rise of 7°F, the power defect for the LEU fuel is estimated to be about .03% $\Delta k/k$ larger in magnitude than for HEU fuel. For a typical FNR configuration, the excess reactivity required to overcome the power defect would thus change from a measured value of .21% $\Delta k/k$ for HEU to .24% $\Delta k/k$ for LEU.

Table 8

Comparison of the Equilibrium Core Parameters with the Actual FNR Parameters

	Equilibrium Core 93% Enrichment	FNR Experience (Oct. 78 - Sept. 79)
Average cycle length (days)	11	8.17*
Average reactivity swing between shuffles (% $\Delta k/k$)	-0.31	-0.40
Average number of shuffles/day	0.82	0.81
Average discharge burnup (%)		
Regular elements	17	17
Special elements	29	34
Calculated k_{eff}		
Range	1.022 ~ 1.026	1.020 ~ 1.032
Average	1.024	1.025
Control Rod Worth (% $\Delta k/k$)	(at beginning of cycle)	(at beginning of Cycle 67)
Shim Rod A	2.21	2.22
Shim Rod B	2.20	2.11
Shim Rod C	2.00	1.72
Total	6.41	6.05

*Includes periods of operation at 1MW power.

9.3.2.2 Xenon Reactivity Worth Comparison

The xenon reactivity worths for the LEU and HEU equilibrium core configurations are compared in Table 9 and in Table 10 for the batch cores. For the cases considered the xenon worth is slightly lower for the LEU than the HEU fuel. There are two competing effects responsible for this decrease: First, the larger ^{235}U loading for the LEU core results in lower in-core thermal flux levels, with a greater (10-12%) xenon concentration. Second, the increased ^{235}U loading gives the LEU core a larger neutron absorption cross-section. As total core absorption is increased, the fractional absorption in xenon, and thus the xenon reactivity worth, is decreased. Although these two effects tend to cancel one another, the latter effect dominates and xenon reactivity worth is lowered by about .1% Δk/k.

9.3.2.3 Control Rod Reactivity Worth Comparison

A comparison of the reactivity worths for shim rods A, B, and C is given in Table 9 for equilibrium cores and in Table 10 for batch cores. As expected, the rod worth is lower for the LEU cores. The greatest loss in total rod worth, .33% Δk/k, is seen for a batch core comparison. For the equilibrium cores, comparing the HEU regular cycle with the LEU cycle corresponding to an equal reactivity change shows a decrease of total rod worth of only .08% Δk/k, indicating that larger core-average burnup in the LEU core can mitigate the decrease in rod worth for the LEU core.

The decrease in rod worth is an expected result of the increased ^{235}U loading required for LEU fuel. When the loading of the principal core absorber (^{235}U) is increased, the control rods become less effective in competing with fuel for neutron absorption and the rod worth is decreased. Accordingly, fuel depletion should increase control rod effectiveness. This prediction is borne out by the equilibrium core calculations displayed in Table 9 and suggests that a longer LEU cycle could provide a means for increasing both control rod reactivity worth and shutdown margin.

9.3.2.4 Comparison of Depletion Characteristics

Depletion effects on reactivity for several equilibrium-core cycle lengths are presented in Table 9. Comparing the 11-day cycle for HEU and LEU cores shows that for equal cycle lengths, the rate of reactivity loss due to fuel burnup is 25% ~30% lower for the LEU core. This is primarily a direct consequence of the increased ^{235}U loading - for a given absolute loss of fuel mass, the fractional depletion and thus reactivity loss are decreased for higher fuel loading. In addition there is a secondary contribution due to the build-up of ^{239}Pu. While the reduction in the rate of reactivity decrease seen for equal length cycles would reduce the excess reactivity requirement, the reduction in control rod worth could result in a net decrease in shutdown margin. Another consequence of the equal-length fuel cycle is that fuel element discharge burnup is reduced, thus likely increasing fuel costs.

Table 9

Core Physics Parameters for Equilibrium Core

	HEU		LEU		
	Regular	Extended	Equal Length	Equal Burnup	Equal Reactivity change
Cycle length (days)	11.0	13.0	11.0	13.0	15.0
Average discharge burnup (MWD/assembly)	19.2	22.8	18.6	21.8	25.3
Core average burnup at beginning of cycle (MWD/assembly)	10.7	12.6	10.6	12.6	14.6
Average reactivity change/cycle (% Δk/k)	- 0.31	- 0.38	- 0.23	- 0.26	- 0.32
Shim rod worth (% Δk/k)					
A Rod	2.21				2.20
B Rod	2.20				2.18
C Rod	2.00	2.06	1.82	1.86	1.95
Total	6.41				6.33
Excess reactivity required (% Δk/k)					
Xenon poisoning	2.24				2.08
Burnup effect	0.31				0.32
Power defect	0.21				0.24
Total	2.76				2.64
Shutdown margin (% Δk/k)	3.65				3.69

Table 10

Core Physics Parameters for Batch Core

	HEU	LEU
Cycle length (days)	10.0	10.0
Reactivity change per cycle (% Δk/k)	- 0.31	- 0.22
Shim rod worth (% Δk/k)		
A Rod	2.37	2.26
B Rod	2.23	2.12
C Rod	2.37	2.26
Total	6.97	6.64
Excess reactivity required (% Δk/k)		
Xenon poisoning	2.50	2.40
Burnup effect	0.31	0.22
Power defect	0.21	0.24
Total	3.02	2.86
Shutdown margin (% Δk/k)	3.95	3.78

Since control rod worth calculations predict an increase in rod worth as fuel burnup is increased, two extended length cycles were investigated for LEU fuel: The first, with a length of 13 days, is intended to match fuel burnup with the 11-day HEU cycle. The second, with a length of 15 days, is intended to yield the same reactivity change per cycle as the 11-day HEU cycle. Results obtained for the two extended LEU cycles, as well as an extended HEU cycle for comparison, are included in Table 9.

Comparison of the 15-day LEU cycle with the 11-day HEU cycle shows that the fuel element discharge burnup is increased by 30%, and the cycle length is increased by 36%, while maintaining approximately equal reactivity change/cycle. These considerations suggest that fuel utilization is expected to be better for LEU fuel and that, over a long period of time, fuel costs could be lowered. This improvement in fuel utilization can be attributed to the small fissile plutonium buildup, increased fast fission due to ^{238}U, and spectrum hardening which reduces the reactivity effects of fuel depletion.

The most important consequence, however, of the extended 15-day LEU cycle is the effect on control rod reactivity worth. The extended cycle length increases the rod worth to a value approximately equal to the regular 11-day HEU cycle.

Since the 15-day LEU cycle offers distinct advantages over the 11- or 13-day LEU cycles, it has been analyzed in detail. Succeeding comparisons of LEU and HEU equilibrium core models will therefore compare the 11-day HEU cycle with the 15-day LEU cycle.

9.3.2.5 Comparison of Shutdown Margin

The most significant safety parameter related to core physics analysis is the shutdown margin. This parameter is obtained by subtracting the positive core excess reactivity required to overcome xenon poisoning, fuel depletion, and the power defect from the total control rod reactivity worth. The present Technical Specifications require that the shutdown margin be at least 3.0% Δk/k. Any difference between the estimated shutdown margin and the limiting value represents excess reactivity available for experiments.

For the LEU batch core, it is seen from Table 10 that the lower excess reactivity requirement is overshadowed by the decrease in control rod reactivity worth. The shutdown margin of 3.78% Δk/k is lower than for the HEU core, but is still well above the 3% Δk/k requirement. Additionally, with the most reactive rod fully withdrawn, the shutdown margin is 1.52% Δk/k, well in excess of the .75% Δk/k required.

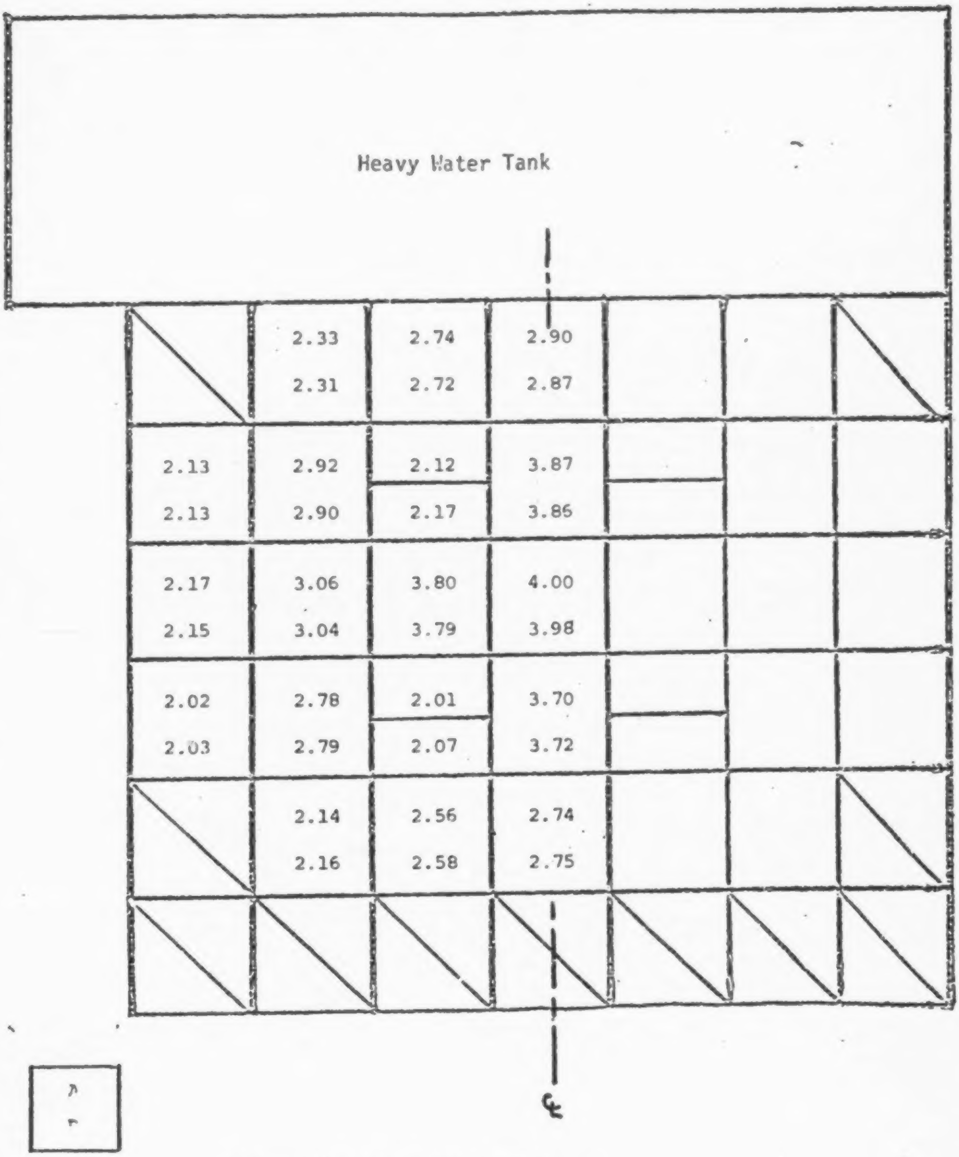
Comparing the HEU and LEU equilibrium core results shown in Table 9, it is seen that for cycles having equal reactivity change, the shutdown margin for the LEU core exceeds that for the HEU core. This rather surprising result is a consequence of the longer cycle length and a higher average fuel burnup in the LEU equilibrium core. With the HEU and LEU control rod worths nearly equalized, the relatively minor effect of lower xenon poisoning increases the shutdown margin slightly. The computed value of 3.69% Δk/k is well in excess of the 3.0% Δk/k requirement. Also, the shutdown margin with the most reactive control rod fully withdrawn in 1.49% Δk/k, well above the .75% Δk/k required.

9.3.3 Comparison of Flux and Power Distributions

Calculated power distributions for both HEU and LEU cores are compared in Figures 9 and 10 for batch cores and equilibrium cores, respectively. Examination of these figures reveals only minor changes between LEU and HEU cores. The largest change in assembly power, a 3% relative increase, occurs for special element locations. Additionally, there is a small shift in the power distribution away from the heavy water tank and toward a slightly improved overall symmetry about the center. There is no evidence of changes which would require detailed thermal-hydraulic analysis; in fact, the ratio of peak to average assembly power is slightly reduced.

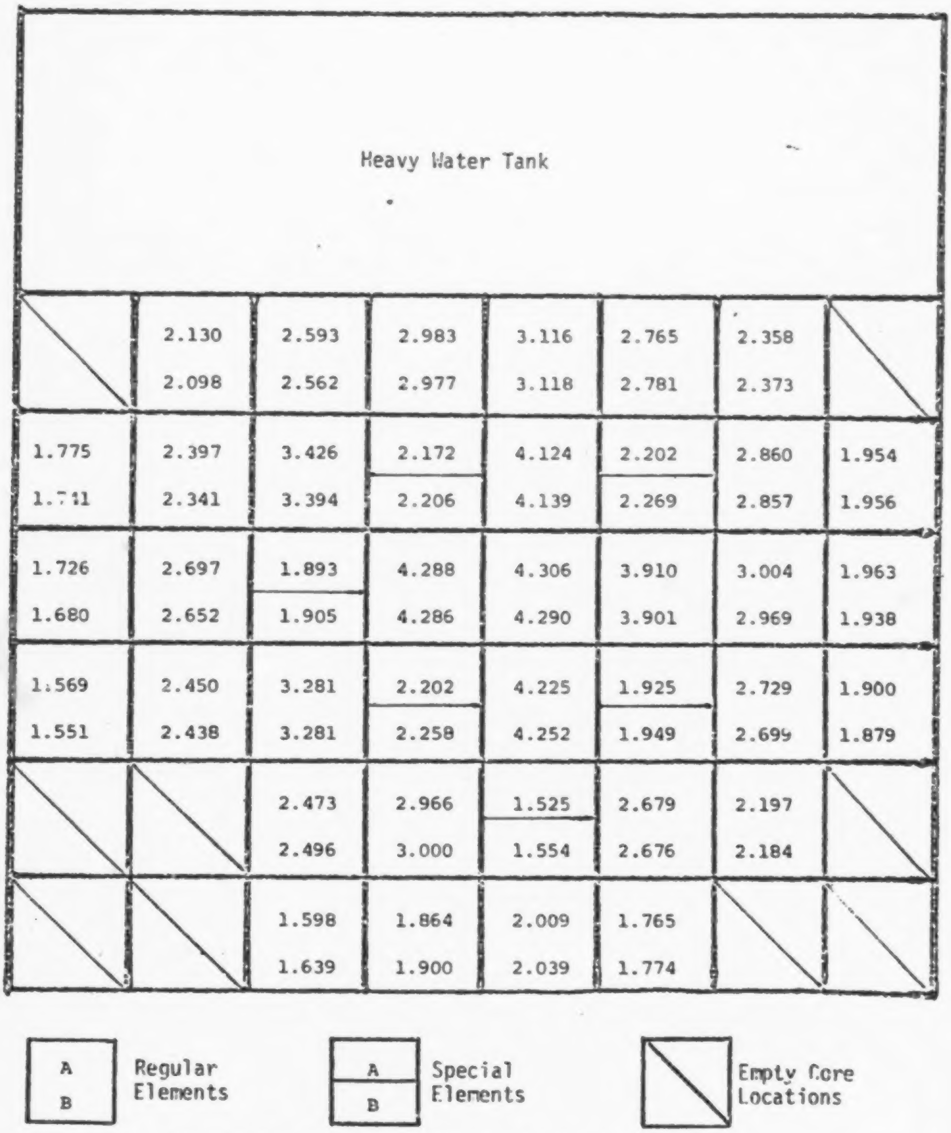
The calculated thermal flux distributions are compared in Figure 11 for batch cores and Figure 12 for equilibrium cores. A major difference between HEU and LEU fuel is apparent from these figures: since for a well moderated core the power is approximately proportional to the product of the macroscopic fission cross-section and thermal flux, an increased fuel loading results in a corresponding reduction in thermal flux for a given power. This effect is readily apparent in Figures 11 and 12, where the thermal flux in regular fuel elements is seen to decrease by about 14%. For special fuel elements, the reduction in thermal flux is only about 9%. This mitigation in the thermal flux decrease results from the effect of the thermal flux peaking in the large waterhole. This peak is primarily dependent on the fast flux, which is not significantly different between the LEU and HEU fuels. Since the thermal flux level within the special element will be affected by the waterhole peaking, the overall effect is to mitigate the decrease in thermal flux. As noted for the power distribution, there is a slight shift in thermal flux away from the heavy water tank toward a slightly improved overall symmetry about the center. Figures 13 and 14 display thermal flux for traverses along the north-south core center lines. It should be noted that the centerline of the equilibrium core is bordered by two special assemblies, whereas the batch core centerline is through the centers of regular assemblies. The general reduction in thermal flux is apparent in both figures, and the mitigating effects of the special assemblies are evident in the equilibrium core traverse.

Calculations of the ex-core thermal flux in the heavy water tank have indicated that the thermal leakage flux will be reduced by 6~10%. While this is an important consideration for experimental usage, it has no impact on the core safety analysis.


Heavy Water Tank
2.33
2.31
2.74
2.72
2.90
2.87
2.13
2.13
2.92
2.90
2.12
2.17
3.87
3.86
2.17
2.15
3.06
3.04
3.80
3.79
4.00
3.98
2.02
2.03
2.78
2.79
2.01
2.07
3.70
3.72
2.14
2.16
2.56
2.58
2.74
2.75
℄
A
B

A: Assembly Power (%), HEU Core
B: Assembly Power (%), LEU Core

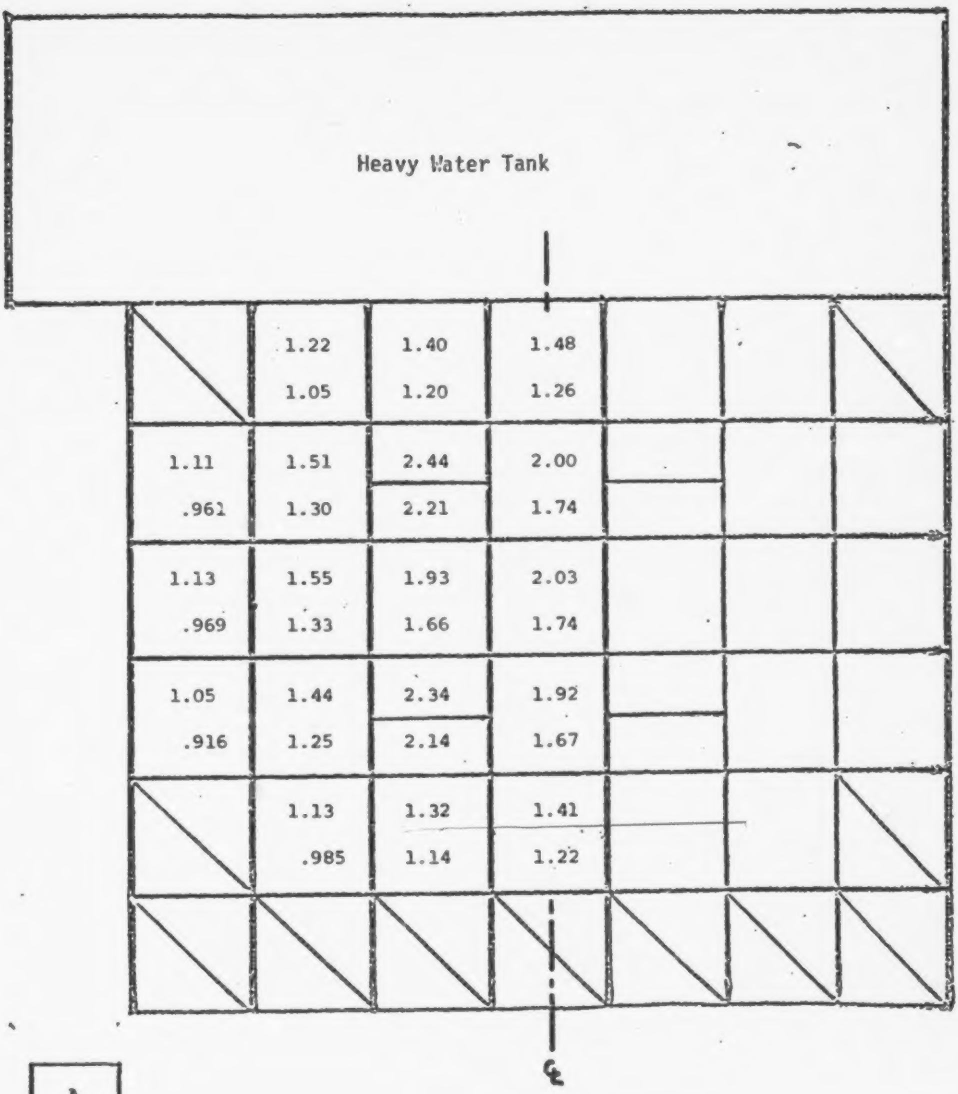
Figure 9. Assembly Power Distribution for Batch Core


Heavy Water Tank
A
B
Regular Elements
A
B
Special Elements
Empty Core Locations

	2.130 2.098	2.593 2.562	2.983 2.977	3.116 3.118	2.765 2.781	2.358 2.373	
1.775 1.741	2.397 2.341	3.426 3.394	2.172 2.206	4.124 4.139	2.202 2.269	2.860 2.857	1.954 1.956
1.726 1.680	2.697 2.652	1.893 1.905	4.288 4.286	4.306 4.290	3.910 3.901	3.004 2.969	1.963 1.938
1.569 1.551	2.450 2.438	3.281 3.281	2.202 2.258	4.225 4.252	1.925 1.949	2.729 2.699	1.900 1.879
		2.473 2.496	2.966 3.000	1.525 1.554	2.679 2.676	2.197 2.184	
		1.598 1.639	1.864 1.900	2.009 2.039	1.765 1.774		

A: Assembly Power (%), HEU 11-day Cycle
B: Assembly Power (%), LEU 15-day Cycle

Figure 10. Assembly Power Distribution for Equlibrium Core



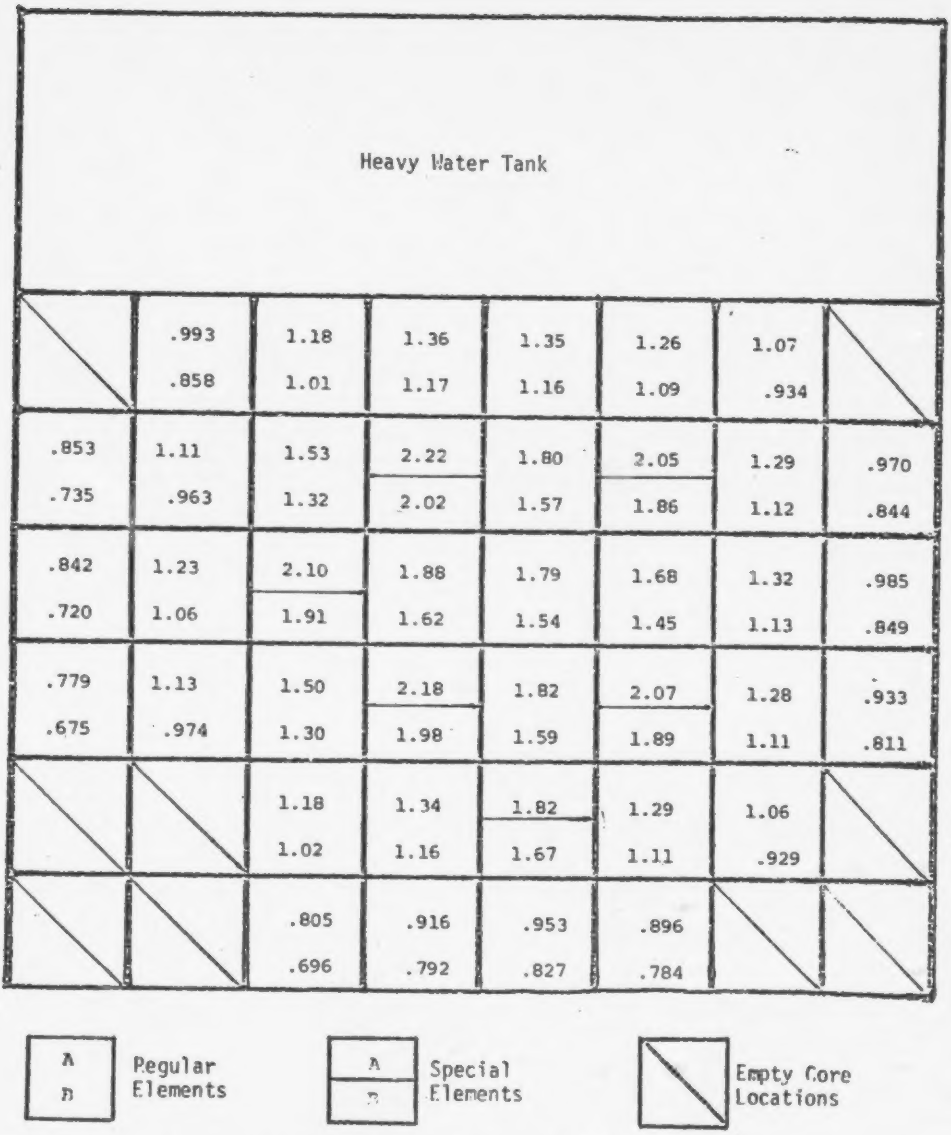
	1.22 1.05	1.40 1.20	1.48 1.26			
1.11 .961	1.51 1.30	2.44 2.21	2.00 1.74			
1.13 .969	1.55 1.33	1.93 1.66	2.03 1.74			
1.05 .916	1.44 1.25	2.34 2.14	1.92 1.67			
	1.13 .985	1.32 1.14	1.41 1.22			

A
B

A: Assembly-Average Thermal Flux (10^{13} n/cm^2·s), HEU Core

B: Assembly-Average Thermal Flux (10^{13} n/cm^2·s), LEU Core

Figure 11. Assembly-Average Thermal Flux Distribution for Batch Core


Heavy Water Tank
A
B
Regular Elements
A
B
Special Elements
Empty Core Locations

	.993 .858	1.18 1.01	1.36 1.17	1.35 1.16	1.26 1.09	1.07 .934	
.853 .735	1.11 .963	1.53 1.32	2.22 2.02	1.80 1.57	2.05 1.86	1.29 1.12	.970 .844
.842 .720	1.23 1.06	2.10 1.91	1.88 1.62	1.79 1.54	1.68 1.45	1.32 1.13	.985 .849
.779 .675	1.13 .974	1.50 1.30	2.18 1.98	1.82 1.59	2.07 1.89	1.28 1.11	.933 .811
		1.18 1.02	1.34 1.16	1.82 1.67	1.29 1.11	1.06 .929	
		.805 .696	.916 .792	.953 .827	.896 .784		

A: Assembly Average Thermal Flux (10^{13} n/cm^2·s), HEU 11-day Cycle

B: Assembly Average Thermal Flux (10^{13} n/cm^2·s), LEU 15-day Cycle

Figure 12. Assembly-Average Thermal Flux Distribution for Equilibrium Core

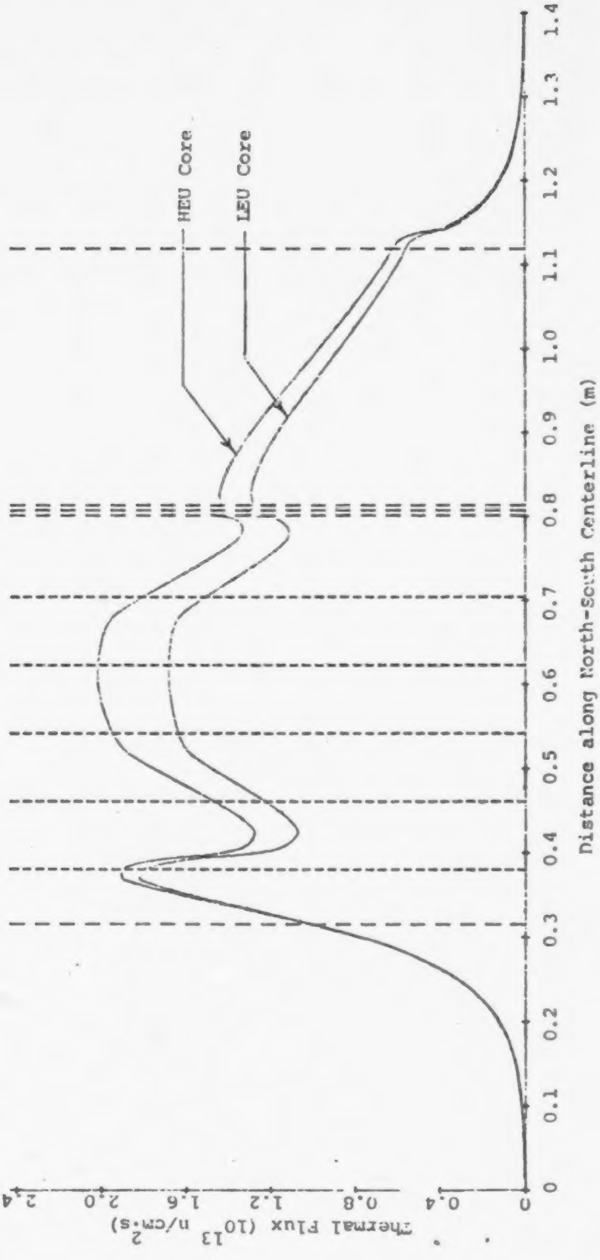


Figure 13. Thermal Flux Distribution for Batch Core

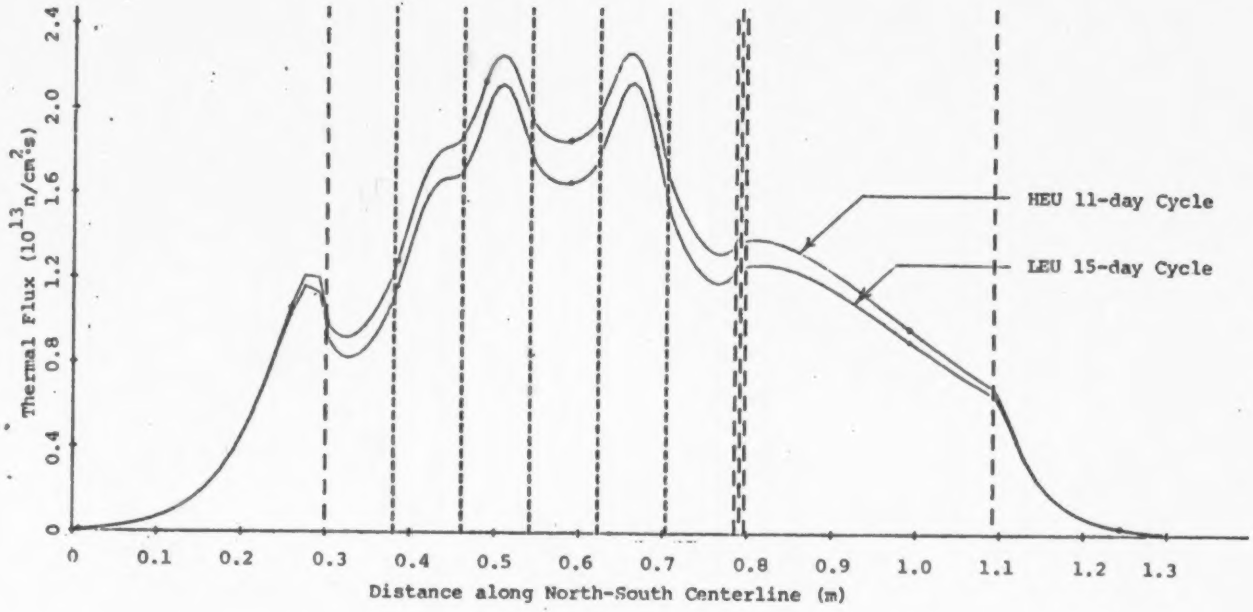


Figure 14. Thermal Flux Distribution for Equilibrium Core

9.3.4 Core Dynamic Characteristics

Of the physics parameter changes that would affect core dynamics, temperature coefficient and power defect, which is largely affected by temperature coefficient, are expected to be the parameters of greatest significance. Calculations indicate the magnitude of negative temperature coefficient increases from -8.4 pcm/°F to -12.6 pcm/°F, primarily due to ^{238}U Doppler. The transient safety characteristics of the core are expected to improve because of the larger negative temperature coefficient and power defect.

The calculated slight decrease in total rod worth still allows for shutdown margins well in excess of Technical Specification limits and sufficient excess reactivity for normal cycle operations. These and other core physics parameters will be verified in the demonstration experiment and measurement program.

The FNR Safety Limits and Limiting Safety System Settings are designed to ensure that fuel clad integrity is maintained. They are based on static combinations of reactor power, core inlet temperature, coolant flow rate, and pool height which prevent boiling in the hottest spot in the core. These limits and settings are not altered by the changes in core physics parameters.

9.4 Summary of the Core Physics Analysis

Extensive effort has been devoted to the development of accurate calculational methods for the analysis of HEU and LEU fueled research reactors. These methods make use of existing well-verified computer codes wherever possible and have been verified through comparison with data from several different research reactor configurations. The accuracy of the computational methods is expected to be equally valid for the prediction of changes in core physics parameters due to the use of LEU fuel. To encompass all expected effects of the proposed LEU fuel, both a batch core model and an equilibrium core model were analyzed in detail and compared with the HEU fuel. The results of these comparisons serve to quantify predictions which can be made on physical grounds: decreasing the fuel enrichment from 93 w/o to 19.5 w/o and increasing the ^{235}U loading from 140 grams to 167.3 grams per 18-plate assembly result in a large decrease in the in-core thermal flux; a small decrease in xenon poisoning; a small increase in power defect due to increased Doppler effects; longer cycle length for a given reactivity change and higher discharge fuel burnup; a reduction in control rod worth, which may be offset by longer cycle; very little change in power distribution; and, most importantly, no significant change in the core shutdown margin.

While there are changes in core physics parameters for the proposed LEU fuel, there appear to be no reductions in any safety margins.

10. DEMONSTRATION EXPERIMENT AND MEASUREMENT PROGRAM

The demonstration experiments and measurements program will: 1) characterize the FNR in sufficient detail to discern and quantify neutronic differences between high and low enrichment cores, and 2) provide measurements to benchmark core physics calculations.

The experiments chosen to accomplish this program are:

1. Wire activation measurements to provide absolute flux normalization.
2. Rhodium detector flux maps to provide absolute thermal (in-core and ex-core) fluxes.
3. Neutron diffraction measurements to determine the flux spectrum in the D_2O reflector.
4. Control rod worth measurements and power defect measurements.
5. Unfolding of foil activation measurements to determine the in-core flux spectrum.

10.1 Analysis of the Current High Enrichment Uranium Core

Experimental and analytical efforts are in progress which are designed to characterize the present FNR core. Spatial flux distributions are being measured with ^{103}Rh movable self-powered neutron detectors, with proper correction factors applied for epithermal neutrons. The measurement of fast neutron spectra are being made using the multiple threshold foil technique and the unfolding calculations (SAND-II and modified SAND-II codes) will be performed. In-core thermal flux spectra are being measured by standard activation foil techniques and Cd ratio methods, and the leakage spectra by crystal spectrometer method. In-core flux, correlated to changes in the reactor core configurations, is being measured by partial-core ^{103}Rh flux maps and the leakage neutron flux levels in beam ports in preparation for partial loading of low-enrichment fuel elements. In addition, measurements of other reactor parameters including control rod worth and reactivity coefficients will be performed. We will also establish, to the extent possible, the accuracy of our measurement techniques so that we can obtain meaningful comparison between the high- and low-enrichment fuels and also with the calculated results.

10.2 Testing and Measurements on the Low-Enrichment FNR Core

Detailed measurements of flux distribution and other reactor parameters for partial- and full-core low-enrichment configurations of the FNR core will be performed. The measurements will be performed in accordance with the techniques established in section 10.1. The need for any modifications in the measurement techniques or detector calibrations for the low-enrichment environment will be determined prior to the full-core loading. The measurements will include in-core and ex-core maps, spectra, and other standard reactor physics parameters.

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Current Status of Neutron-Scattering Research and Facilities in the United States

Panel on Neutron Scattering
Solid State Sciences Committee
Board on Physics and Astronomy
Commission on Physical Sciences, Mathematics,
and Resources
National Research Council

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PREFACE

In the spring of 1983, the Solid State Sciences Committee, in implementing one of a series of studies addressing the health of this discipline, called together a group of experts to assess the present status of U.S. facilities and capabilities in the field of neutron-scattering research. The Panel was also asked to review recent trends in the U.S. neutron-scattering user community and to identify critical gaps in U.S. capabilities in this field with respect to those abroad. The Panel was charged to address primarily applications of neutron-scattering techniques in the condensed-matter, chemical, and biological sciences. It should be noted that a number of other critical scientific and technological areas (some of which are listed in Chapter 3 of the report) require the use of high-performance neutron sources. It is clear that these applications will have important implications in any discussion of the design and utilization of neutron sources in the future.

The Panel concluded that the United States has fallen behind Western Europe in the use of cold neutron beams and high-resolution spectroscopy. U.S. reactors remain world class in terms of neutron-beam intensities, but the United States lags in the development of new instrumentation on the reactors. An additional problem is that they are aging. Existing sources will be 20 to 25 years old by 1990. The long-range implications are serious with respect to many fundamental new applications of neutron-scattering research in the materials-related disciplines, including those of technological importance.

The Panel's report stresses the need for an immediate U.S. commitment to the development and installation of state-of-the-art instrumentation at our present research reactors; for support to permit full investigation and development of pulsed sources; and to begin planning for the next generation of neutron sources. The Panel emphasized the importance of involvement of the user community in all stages of planning of new facilities.

The Solid State Sciences Committee unanimously endorses the Panel's conclusions and recommendations. We urge the federal research agencies to move as quickly as possible to strengthen U.S. capabilities in this highly competitive and technologically promising field of research.

William F. Brinkman, Chairman
Solid State Sciences Committee

1. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. In the last decade neutron-scattering research worldwide has shown a rapid expansion both in the number of users and in the diversity of disciplines and science to which neutron methods are being applied. This growth is due to the development of improved sources and new instruments, which have greatly enhanced the energy and wave-vector range, resolution, and sensitivity of neutron instrumentation. The neutron-scattering community in Europe more than tripled during the 1970s. By comparison, the U.S. community has doubled over the past 6 years, accompanied by a 150 percent increase in users from less-traditional areas--polymers, biology, and materials science.

2. In spite of some recent progress, the United States has fallen far behind Western Europe in the development of advanced facilities at research reactors, including modern applications of cold sources and guide-tube technology, focusing monochromators, and spin-echo and backreflection techniques. These advances have led to many fundamentally new applications of neutron scattering, which touch on all materials-related disciplines, including technologically important areas. The United States has maintained its competitive position and tradition of excellence in such areas as thermal-neutron triple-axis spectroscopy and chemical

and biological crystallography and, for the present, is at the forefront in pulsed-source research.

3. Current U.S. reactors remain world class in terms of available thermal-neutron-beam intensities, and there are immediate opportunities to achieve an internationally competitive status in advanced instrumentation for both cold and thermal neutron scattering at a cost substantially lower than the recent European expenditures. Such modern facilities, combined with emerging applications of pulsed-neutron sources, would stimulate greatly expanded use of neutrons to meet new scientific and technological needs and opportunities until new-generation sources are developed. It should be noted that existing sources will be 20-25 years old by 1990.

RECOMMENDATIONS

1. The Panel recommends that an immediate commitment be made to develop new state-of-the-art instrumentation at our high-performance research reactors to provide world-class capabilities in such areas as high-resolution and high-sensitivity neutron spectroscopy, small-angle scattering and diffraction, medium-resolution macromolecular diffraction, and diffuse scattering. This will require the extensive development and application of modern cold-source and guide-tube technology, focusing and polarizing monochromators, and area detectors.

2. The Panel recommends that adequate support be provided to allow full investigation and development of new pulsed-source instrumentation required to exploit the unique opportunities in condensed-matter research provided by the

pulse structure, higher fluxes of epithermal neutrons, and expanded wave-vector range of spallation sources.

3. The Panel considers it essential that serious design efforts be started immediately for the development of next-generation sources, so that definite proposals are available by fiscal year 1988. The results of such efforts are essential as input to a broadly based user group, which should be established to recommend a coherent plan to meet the long-term neutron research needs of the scientific community. It is the view of this Panel that the National Academy of Sciences-National Academy of Engineering would be the most appropriate body to establish such an independent multidisciplinary advisory group.

2. INTRODUCTION

The development of neutron-scattering facilities and research applications worldwide has shown dramatic growth and change during the past decade. The most notable example of these changes is found in the emergence of the British/French/German Center at the Institut Laue-Langevin at Grenoble, but its development is only part of a major transformation of the field that has occurred throughout Western Europe and more recently in the United States and Japan. Over the past 25 years the unique characteristics of the neutron as a probe of condensed matter has transformed much of our fundamental understanding of the physics and chemistry of materials. In the last decade a new generation of cold and thermal neutron instruments has been developed (particularly in Europe) that has extended the wave-vector range and energy resolution for neutron experiments by orders of magnitude. These in turn have opened up new research in physics and chemistry and have greatly expanded the application of neutron scattering in new areas—materials science, polymers, and biology. For example, the neutron-scattering community in Europe has tripled in the past decade, and, more recently, there has been a great increase in the size of the neutron-scattering community in the United States. Moreover, in the past few years the development of higher-intensity pulsed neutron sources has also created new opportunities for neutron-scattering research using higher neutron energies. The impact of these emerging neutron-research opportunities on U.S. science has been addressed by two reports over the past 6 years: the NAS-sponsored study, Neutron Research on Condensed Matter in 1977 and the Report of the Review Panel on Neutron Scattering, sponsored by the U.S. Department of Energy (DOE), which in 1980 presented a study of U.S. neutron-research capabilities centered around priority recommendations for neutron facilities of the DOE. We refer the reader to these earlier studies for a detailed review of the unique role of the neutron as a probe of materials. Both of these reports emphasized the much greater investment and facility advances that were being made in overseas neutron-scattering research and recommended steps to be taken to assure an internationally competitive position for the United States in neutron scattering. While some of these recommendations have been addressed at least in part, most have not, and total funding has shown little change in real dollars over the past 6 years. The present study is the response to a request by the Solid State Sciences Committee of the National Research Council, and attempts to provide an objective up-to-date assessment of the current status of U.S. research accomplishments and capabilities in this fast-moving field, including a review of recent trends in the American neutron-scattering user community. Critical gaps in U.S. neutron-research capabilities with respect to modern facilities at other international centers are also highlighted.

3. CURRENT STATUS OF NEUTRON-SCATTERING FACILITIES IN THE UNITED STATES

In this chapter we describe briefly the existing neutron-scattering facilities at the five National Laboratory neutron sources and two major university reactor facilities. We also provide a summary of the trends in users and publications associated with U.S. neutron facilities. In Chapter 4 we provide a comparison with facility development and user trends at foreign laboratories.[1] It is clear from these data that there has been a striking increase in users and change in user patterns over the past decade along with qualitatively new research opportunities in a variety of fields.

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[1] A variety of sources of information were used by the Panel in assembling summaries of users, publications, instrumentation, and total neutron-scattering budgets. These included the earlier National Academy of Sciences and Department of Energy reports cited in the Introduction, the Annual and special reports of the DOE and its National Laboratories, the National Bureau of Standards, and the University of Missouri, along with those of the Institut Laue-Langevin at Grenoble and other neutron-scattering centers in Europe. The Panel went further, however, to assure up-to-date suitably coordinated information and statistics by individually contacting the major neutron centers in the United States, Western Europe, Japan, and Canada concerning users, publications, and other information relevant to the comparisons made in the report. It should be noted that the Panel did not attempt to provide similar comparisons with neutron-scattering facilities in the Soviet Union, Eastern Europe, India, or other neutron efforts worldwide. A summary of these facilities can be found in the earlier NAS and DOE reports mentioned above.

It should be noted that in general U.S. neutron sources also serve a wide variety of scientific and programmatic needs that are unrelated to neutron-scattering research. At present, about half of the total operating costs of major neutron sources (about $13.5 million) are associated with neutron scattering, while the remainder is related to other highly important and diverse national needs, including isotope production, chemical trace analysis, radiation damage, nuclear physics, ultracold neutron research and radiation standards. This multiple program use of neutron sources in the United States is beneficial, since it can provide broad-based support and cost-effective operation. However, it can sometimes create serious difficulties if one of the programs loses or withdraws support, thus threatening the stability or schedule of source operation.

The major neutron sources in the United States used for scattering research are briefly described in the following summaries. The research reactors in general operate 24 hours a day in a quasi-continuous schedule with brief shutdowns for maintenance and refueling. The pulsed-source schedules are currently more curtailed, as noted in the summaries.

FACILITY DESCRIPTIONS

High Flux Beam Reactor (HFBR)—Brookhaven National Laboratory

The High Flux Beam Reactor is a 60-MW reactor using enriched fuel and D_2O as a moderator and primary coolant. The core is small (48-cm diameter), resulting in a thermal neutron density that is peaked outside of the core, where beam tubes tangential to the core provide neutron beams with low fast-neutron contamination. The thermal flux is 1 x 10^{15} neutrons/cm^2-sec at the 8-cm-diameter thermal beam-tube tips. To provide intense beams of low-energy neutrons, a liquid H_2 moderator has been installed in one beam tube that is equipped with a small-angle scattering diffractometer and a high-resolution three-axis spectrometer. Situated on the seven remaining tangential beam tubes are four conventional three-axis spectrometers that are used mostly for inelastic scattering studies and powder diffraction, a three-axis spectrometer and two diffractometers equipped with four-circle goniometers for single-crystal and protein diffraction studies, as well as two additional diffractometers used mainly for small-angle scattering. Four diffractometers have position-sensitive detectors. One of the three-axis spectrometers is often devoted to polarized neutron studies. Under a cooperative development are a new polarized-beam crystal spectrometer with a spin-echo capability (with Japanese scientists) and a medium-resolution macromolecule diffractometer (with Exxon Research Laboratories). Additional ancillary equipment, including conventional and ^{3}He cryostats and high-pressure sample environments are routinely available. Staff scientists carry out independent research programs in addition to assisting external users, who make collaborative arrangements largely through direct contact with interested staff scientists. A more formal user policy including peer review will be implemented in the near future.

Intense Pulsed Neutron Source (IPNS)--Argonne National Laboratory

The Argonne Pulsed Neutron Source produces bursts of neutrons with a peak thermal flux of ~4 x 10^{14} neutrons/cm^2-sec at a repetition rate of 30 Hz and is at present the most intense pulsed source in the world. Neutrons at the IPNS are produced by a 450-500 MeV proton-beam incident on a depleted uranium target at an average current of ~12 μA. A polyethylene moderator surrounds the target to reduce the energy of the neutrons to allow neutron-scattering research. Twelve horizontal and two vertical beam holes surround the moderator assembly. A cold moderator (80K) is available for three of the beams. A separate uranium target is used for fast-neutron irradiation and arranged so that the samples can be irradiated at liquid helium temperature. IPNS currently operates 6 months a year. The radiation effects facility receives the beam 25 percent of the time, and the neutron-scattering target 75 percent of the time.

There are seven instruments currently available in the user mode, including two high-resolution powder diffractometers; a single-crystal diffractometer operating on the Laue principle with a position-sensitive detector of the scintillation type; a small-angle diffractometer, also with a position-sensitive detector; a crystal-analyzer spectrometer primarily for observing H-modes in chemical systems; and two chopper spectrometers with incident energies ranging from 50 to 1000 MeV, which allow scattering measurements over a broad range of energy and wave-vector transfer. These neutron-scattering instruments are scheduled in the "user" mode, i.e., allocation of 75 percent time is made by a Program Committee, which reviews proposals twice a year. Three additional instruments are under development: a polarized neutron instrument for studying refraction from surfaces; a diffractometer built to search for ordered nuclear moment arrangements in ^{3}He below 1 mK; and a spectrometer for spectroscopy in the electron volt range.

Accelerator modifications and installation of an enriched uranium target are planned over the next 2 years to increase significantly the intensity of IPNS.

Massachusetts Institute of Technology Reactor (MITR)

The MITR is a 5-MW, heavy-water moderated reactor whose core and beam arrangement was modernized in the 1970s to provide beam tubes with accessible fluxes approaching 10^{14} neutrons/cm^2-sec. There are currently three two-axis spectrometers in use, one with temperature stability control for neutron interferometer studies and two for general-purpose diffraction with changeable monochromators and wavelengths. The MITR is also utilized for a variety of other research and applications in nuclear engineering, trace analysis, radiation effects, and isotope production.

National Bureau of Standards Reactor (NBSR)

The NBSR is a heavy-water-moderated research reactor currently operated at 10 MW and awaiting final Nuclear Regulatory Commission approval to double the power to 20 MW, which will provide a flux at the beam-tube entrances of 2 x 10^{14} neutrons/cm^2-sec. The NBSR has eleven radial beams (15-cm diameter), nine of which are currently dedicated to neutron-scattering research. The reactor geometry combines a split-core fuel arrangement and large vertical divergence (~100 min) to provide high-intensity, low-background beams at the sample position for scattering applications. The facilities available for diffraction include a multiple-detector high-resolution powder diffractometer; a four-circle single-crystal diffractometer; a biological crystallography station (NBS-NIH) using a position-sensitive detector; a small-angle-scattering spectrometer that features a focusing collimating system, tunable wavelength (4.5-12 Å), and a large (65 cm x 65 cm) position-sensitive detector that can be rotated around the sample. Instruments for inelastic scattering include three variable-incident energy triple-axis spectrometers, one of which is equipped with a high-intensity beryllium filter analyzer for chemical spectroscopy, and a multidetector time-of-flight crystal-chopper spectrometer with variable incident energy. A polarized-beam spectrometer is also under development. Scattering experiments are possible between 0.3 and 1800 K and at magnetic fields up to 7 T. All neutron-scattering instruments are scheduled each month by a committee of major users from the National Bureau of Standards, other federal laboratories, and universities. External requests for facility use can be addressed to committee members or to the neutron group leader.

Funding has recently been provided for installation of a large (25-cm-long, 36-cm-diameter) cold-neutron source in the reactor core, which will serve a variety of instruments for cold-neutron research on materials.

Sixteen other facilities at the NBSR serve research and applications in chemical trace analysis, radiation standards, nuclear physics, and isotope production.

Oak Ridge National Laboratory Reactors (ORNL)

The High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory operates at a power level of 100 MW. Light water serves as coolant and moderator in the annular fuel region. Target rods for production of transuranium isotopes are located in a central flux-trap region. There are four horizontal beam tubes of 10-cm inner diameter with an average flux of 1 x 10^{15} at their tips. These beams deliver neutrons to nine scattering instruments: two variable incident energy (E_0) triple-axis spectrometers; a fixed E_0 triple-axis unit; a polarized-beam triple-axis spectrometer; an ultrasonically pulsed time-of-flight instrument; a liquid diffractometer; a four-circle, single-crystal diffractometer; a double perfect-crystal small-angle scattering (SANS) instrument; and a 30-m SANS facility with an area detector. The last instrument was constructed with NSF funds and is operated by the National Center for Small-Angle Scattering Research. A new high-intensity two-axis diffractometer with a curved position-sensitive detector is being developed with Japanese support with a potential for real-time crystallographic studies.

The Oak Ridge Research Reactor (ORR) operates at 30 MW with light water as coolant and moderator and beryllium as reflector. The primary purpose of this reactor is for materials-irradiation experiments, but there are six horizontal beam tubes of 17-cm diameter for scattering experiments. The thermal flux near the beam-tube entrances is about 2 x 10^{14} neutrons/cm^2-sec. The Ames Laboratory operates three instruments at the ORR: a variable-E triple-axis diffractometer, a polarized-beam diffractometer, and a two-axis diffractometer.

In addition, ORNL operates a 5-m SANS instrument with an area detector and a two-axis diffractometer.

Proposals for the NSF-supported SANS facility are reviewed by a special committee and scheduled as they are received; there is normally a three- to four-month waiting period. Other ORNL instruments are available to users either by informal arrangements or by written proposals that are reviewed by Oak Ridge staff members.

University of Missouri Research Reactor (MURR)

MURR is a 10-MW pressurized-water, beryllium-reflected flux-trap reactor located in Columbia, Missouri. There are six beam ports with four used for neutron-scattering research. The flux available at the source end of the beam ports is 10^{14} neutrons/cm^2-sec. There are currently seven neutron-scattering instruments: two four-circle single-crystal diffractometers; one triple-axis spectrometer; two powder diffractometers--one with a position-sensitive detector, the other with a five-detector system; a fixed-wavelength (4.7 Å) small-angle scattering facility that uses a multidetector and has 4.5-m flight paths before and after the sample; and a double-crystal monochromator-interferometer instrument. Facilities are open to outside users by informal arrangements with neutron-scattering staff members at MURR.

The reactor has a number of other major facilities used for gamma-ray scattering (diffraction, quasi-elastic scattering, and Compton scattering), neutron activation analysis, radio-pharmaceutical and transmutation-doped silicon production, radiation-effects studies, neutron radiography, and keV neutron beams for tomography and cross-section work.

An improved triple-axis spectrometer and another diffractometer are expected to be built during the next 2 years, and an engineering study has been funded for a possible doubling of the reactor power.

Weapons Neutron Research/Proton Storage Ring Facility (WNR/PSR)
Los Alamos National Laboratory

The WNR/PSR being developed at the Los Alamos National Laboratory is a pulsed spallation neutron source for neutron-scattering research in condensed-matter physics, chemistry, materials science, biology, and polymers. It is an interdisciplinary facility that is shared with nuclear- and neutrino-physics research. A beam of 800-MeV protons is provided by the Los Alamos Meson Physics Facility (LAMPF). At present, the WNR can utilize only about 0.5% (~5 μA) of the LAMPF beam. However, the PSR will permit by 1986 the use of 100 μA of LAMPF protons with a much reduced pulse width of 0.27 μsec. At that time, the peak thermal neutron flux in the pulse is expected to be 10^{16} neutrons/cm^2-sec at 12 Hz, making WNR/PSR directly competitive in neutron intensity with the new British pulsed source (SNS) at the Rutherford Laboratory.

At present six beam lines are available for condensed-matter research, three each for elastic and inelastic scattering studies. Two of these instruments, a filter difference spectrometer for vibrational spectroscopy and a single-crystal diffractometer, are operated in a user mode, while the remaining instruments are under development. A general-purpose powder diffractometer is expected to become a user instrument in 1984. A program advisory committee (shared with ANL) currently meets twice a year to decide on proposals for beam time. The total time available for neutron-scattering studies currently is 60 percent of the LAMPF operating schedule (6 months/year in 1982-1983) and will increase to 80 percent in 1986. A total of ten neutron-scattering instruments is planned for completion by the end of 1986.

Summary of Facilities

Other neutron-diffraction facilities also exist at smaller university reactors for student training and research, most notably several instruments at the University of Rhode Island. In Table 1 we summarize the neutron-scattering instruments currently available at major U.S. neutron sources. The table shows that there are a total of 53 instruments (compared, e.g., with 114 instruments currently operating and over 40 under development in Western Europe). The relative effectiveness of these facilities is, of course, closely related to intensity, energy and momentum range, and flexibility, for example, factors that are impossible to reflect in a single table. In general, current neutron-scattering capabilities in the United States are clearly still competitive internationally in the areas of triple-axis spectrometry with resolutions $\geq$0.2 meV, single-crystal and powder diffraction for both steady-state and pulsed sources, polarized-beam research, high-resolution biological diffraction, and neutron interferometry. In a later section, critical neutron instrumentation and measurement capabilities currently unavailable or not fully competitive in the United States will be summarized.

TABLE 1 Summary of Neutron-Scattering Instruments Available in the United States

A. RESEARCH REACTORS

1. Diffractometers

	Two-Axis	Two-Axis (Multisector or PSD)	Four-Circle	Four-Circle (PSD)
BNL	-	1	2	1[b]
MIT	2	-	-	-
NBS	-	1[a]	1	1[b]
ORNL	1	1	1	-
MURR	-	2	2	-

2. Spectrometers

	Interferometer	SANS	Three-Axis	Time-of-Flight	Polarized Beam
BNL	-	2[b]	5[c]	-	-
MIT	1	-	-	-	-
NBS	-	1	4[c]	1	-
ORNL	-	3	4	1	2
MURR	1	1	1	-	-

B. PULSED NEUTRON SOURCES

1. Diffractometers (Elastic)

	Powder	Single Crystal	SANS	Beam
ANL	2[a]	1	1	1
LASL	1	1	-	-

2. Time-of-Flight Spectrometers

	Chopper Analyzer	Crystal Analyzer	Filter Analyzer
ANL	2	1	-
LASL	-	-	1

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[a] Dedicated high-resolution powder diffractometers.

[b] These instruments configured primarily for biological structure research.

[c] One of these three-axis instruments is sometimes used for polarized beam studies.

[d] Primarily for structure of liquids and glasses.

It should also be noted that aside from the facilities described above, there are ongoing state-of-the-art efforts at the various neutron centers in the development of area detectors, multilayer focusing and polarizing monochromators, focusing collimators, neutron interferometers and choppers, all of which are important for the development of advanced instrumentation for reactor or pulsed sources. While in some cases U.S. laboratories have been pioneers in such advances, our efforts in general have a low-to-modest level of support and manpower compared with instrumentation development projects in Europe (some of which are described below). As a result, the implementation of new classes of instruments based on these developments has been generally much slower in the United States.

THE USER COMMUNITY

The U.S. neutron-scattering user community has changed considerably since the 1977 report of the National Research Council (Neutron Research on Condensed Matter, National Academy of Sciences, Washington, D.C., 1977), both in the number of users and in the kinds of science being done. A summary of the total number of users per year at U.S. neutron-scattering facilities during the past 6 years is given in Figure 1. For the purposes of this report a "user" has been defined as a scientist who directly participated in a neutron-scattering experiment at least once during a given year. A scientist who visited a given neutron center more than once to perform experiments is counted only once.

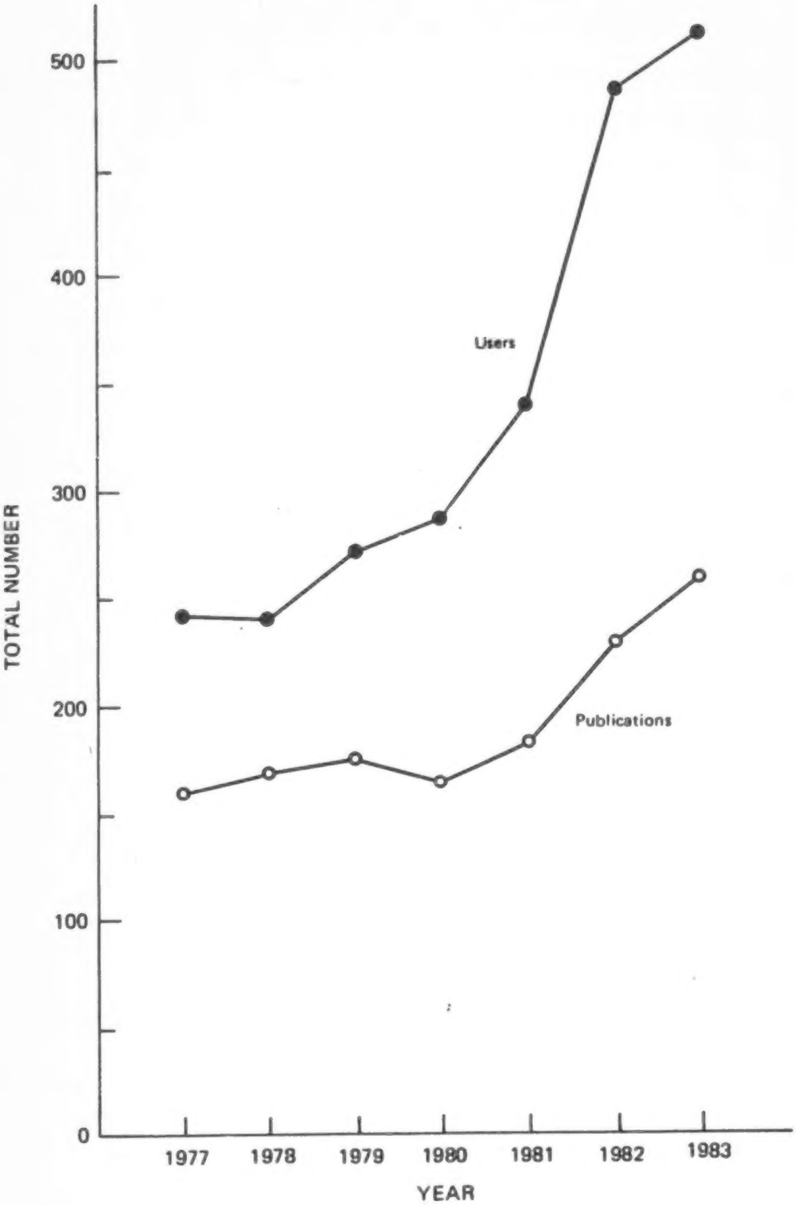

FIGURE 1 U.S. neutron-scattering research--users and publications.

No attempt has been made to identify scientists who might have used more than one neutron source. Also shown in Figure 1 are the number of publications in the 1977-1983 period.

The user trends in Figure 1 show that the number of U.S. users of neutron-scattering facilities has more than doubled during the past 6 years and has gone up 80 percent between 1980 and 1983. This rapid increase in the total user community is broadly reflected in the individual numbers for the majority of the neutron research centers. Major factors include the installation of new or improved small-angle scattering facilities at the research reactors, the commissioning of the Intense Pulsed Neutron Source at Argonne National Laboratory, and other reactor instrumentation developments including high-resolution diffraction and improved polarized-beam and triple-axis spectrometers. It should be noted that this large increase occurred in spite of the shutdown of the CP-5 reactor at Argonne during 1978-1979. It is clear from the user trends that, as has occurred in Europe, the introduction of new or improved neutron instruments that provide new measurement capabilities greatly increases the utilization of such neutron facilities by the scientific community.

The expanded neutron-scattering community shown in Figure 1 also reflects a significant change in the distribution of users from the various scientific disciplines and in some cases the introduction of almost entirely new user groups (e.g., polymer science). In broad terms, the neutron user community in 1983 is distributed as follows: condensed-matter physics, 35 percent; chemistry, 23 percent; materials science, 16 percent; polymer science, 13 percent; biology, 13 percent. Thus while condensed-matter physics has shown a healthy increase over the past 6 years (~33 percent), these users now represent a considerably smaller percentage of the total community than in 1977 (~45 percent). Other user groups, most notably in polymer and materials science and biology, have shown much greater relative increases (~150 percent), stimulated largely by the availability of new state-of-the-art SANS and high-resolution diffraction facilities. The chemistry community has also grown at approximately twice the rate of the condensed-matter physics community.

Since the number of full-time scientists at the major neutron centers has increased very little during the past few years, these numbers represent a decided increase in part-time users of neutron-scattering facilities. In fact, this has put a great strain on the scientific and technical staff at the National Laboratories in seeking to serve the increasing user community while continuing to meet the program needs of their own agencies. Currently the approximate distribution of users is as follows: federal laboratories and agencies, 30 percent; universities, 60 percent; and industry, 10 percent.

The breadth of the current neutron-scattering community is reflected in the diversity of the organizations that participate in research at the various neutron centers. A list of universities, industries, and laboratories doing independent or cooperative neutron research during this past year is given in Appendix A. One notable trend in the user distribution is the considerable increase over the past 6 years in the number of students using neutron-scattering facilities either full time or part time in their research. Between July 1982 and June 1983, there were 92 student users at the various neutron centers. This number is both significant and encouraging since the education and participation of young scientists in modern neutron-scattering science is essential for the future health and vitality of the field. It should be noted here that, while the majority of users utilize the federal laboratory facilities (almost 90 percent in 1983), the university facilities have trained or provided facilities for close to 30 percent of the student users.

Another measure of the productivity and vitality of the neutron-research community is, or course, the number of publications resulting from the use of neutron-scattering facilities. The publication numbers assembled from the various neutron centers for the past 6 years are shown in Figure 1. It can be seen that a large increase in neutron-scattering publications has occurred that roughly parallels the rapid increase in the user community. Thus we observe an increase of slightly more than 60 percent over this period, almost all during the past 3 years. This increase is smaller than the overall percentage increase in users. This lag is to be expected for new users (in many cases using new facilities) in any field. In fact an even greater lag in publications was noted during the rapid expansion of users at the Institut Laue-Langevin (ILL) in Grenoble during the 1970s. In addition it should be noted that part-time users of any major facility will rarely be as productive in publication as the core of full-time users (who represented a much larger fraction of the total neutron user community in the mid-1970s). As will be seen below, the current number of publications per user compares quite favorably with comparable figures for the ILL and other European facilities.

It is also interesting to note that a combination of the facility numbers in Table 1 with the user figures in Figure 1 gives about 10 users/instrument. This is rather close to the comparable ratios assumed for synchrotron facilities in the Report of the Subcommittee on U.S. Synchrotron Radiation Facilities (Current Status of Facilities Dedicated to the Production of Synchrotron Radiation, National Academy Press, Washington, D.C., 1983).

COMPARISON WITH THE EUROPEAN COMMUNITY

We now present a brief review of foreign neutron-scattering users and facilities, concentrating on Western Europe, where the major expansion has occurred during the past 12 years. Western Europe has over the last decade developed a user community more than double the size of that in the United States, driven by a major investment (most notably at the ILL) in new classes of instrumentation and a highly organized, well-funded user policy. A summary of users and publications over the past 6 years is given in Figure 2. In developing the user numbers we have applied the same criteria as we outlined above for the United States, but there is a greater uncertainty in the "user" figures for non-ILL facilities owing to the greater chance of "double counting" scientists who use both ILL and their own neutron facilities. It should be noted that while the total European user community tripled during the 1970s, the period shown in Figure 2 shows a less dramatic rise, reflecting the saturation of facilities at ILL and elsewhere. A notable feature of these current-user

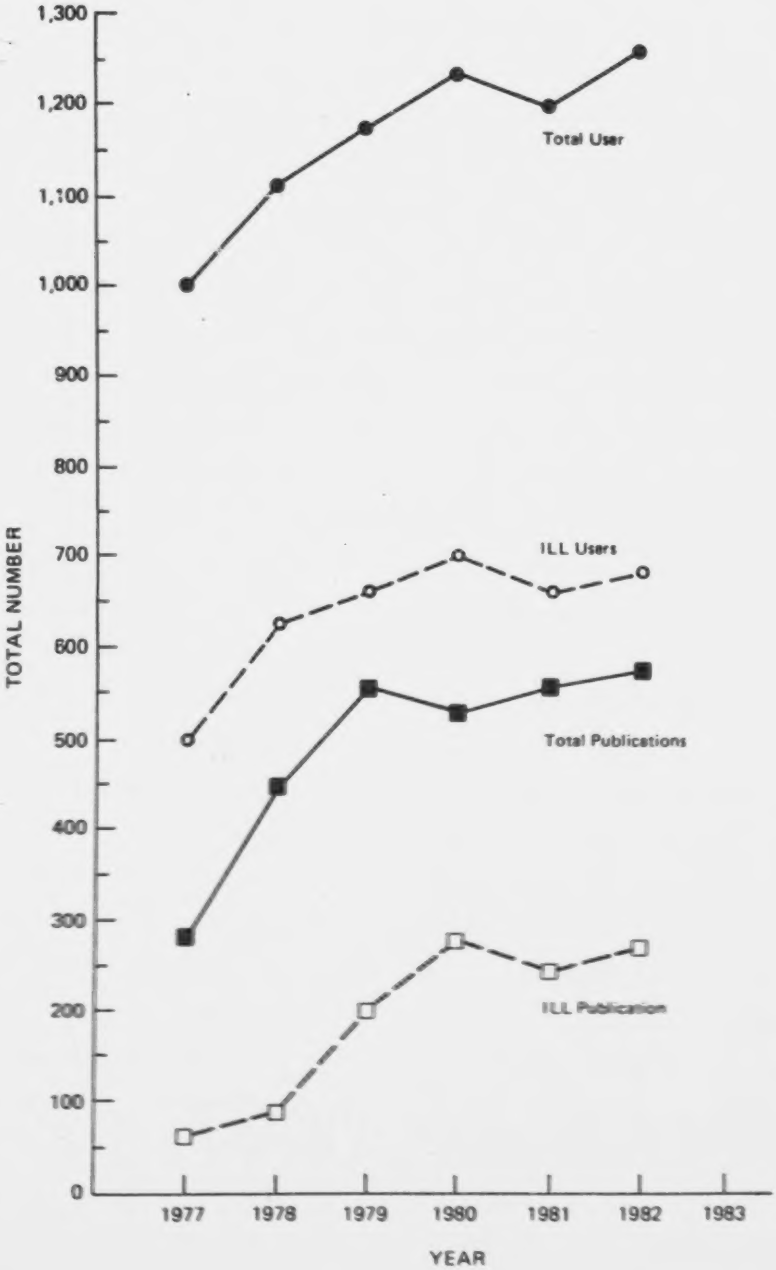

FIGURE 2 Summary of users and publications from Western Europe.

numbers is the dominant position of ILL, which accounts for about half of the users and publications in Western Europe. In fact, the figures show that the ILL alone has about 25 percent more "users" than the total for the United States. The current number of neutron-scattering instruments at the ILL is 26, and the total annual budget (including a program to fund the expenses of users from France, Germany, and Great Britain) is about $25 million (roughly the same as the entire U.S. effort in neutron-scattering research). Taking into account the rapid development and planning of new instruments (~50) in Western Europe, a user community exceeding 1500 would be expected by about 1987.

Beam time on the ILL is scheduled almost entirely in the "user" mode through the review of formal proposals by panels assembled to represent various disciplines and kinds of instruments. In addition, every neutron facility has instrument-responsible scientists and technicians associated with it who are assigned to assist outside scientists in using the facilities. While the average number of users per instrument per year in this mode (about 20) is considerably higher than in the United States, the number for the United States (10) is somewhat higher than the average of the other European facilities. Publication rates per user are roughly the same for the United States as for Western Europe. By comparison, figures for neutron-scattering publications in Canada, which has maintained a traditional role in this field, show an average rate of about 40 publications in recent years. The Japanese, who are engaged in a vigorous expansion in both reactor-based and pulsed neutron research, now show a publication rate approaching 100 papers per year. While these comparisons attest to the continuing productivity of the U.S. neutron centers, the U.S. ability to serve the needs of the user community is limited by the lack of incremental resources for scientists and technicians to provide direct user support at the major neutron centers.

Another key problem facing the U.S. neutron facilities in seeking to maintain an internationally competitive position in this field is the lack of resources for the development of new classes of instrumentation (leading to new science). A major advantage of the ILL and other European centers over the past decade has been the flexibility and funding to develop such new instruments and the cold neutron sources, guide tubes, and focusing monochromators, for example, needed for their development. In the next chapter we will briefly review the impact of this relative lag in U.S. capabilities.

4. OVERSEAS NEUTRON-SCATTERING FACILITIES

RESEARCH REACTORS

In this chapter we provide a selective review of foreign neutron-scattering facilities, concentrating on instrumentation developments that have not been matched in the United States. Current activities in the modernization or expansion of facilities in Western Europe and Japan will also be summarized. Again much of our focus with respect to steady-state neutron sources will be on the rapid developments over the past decade at the Institut Laue-Langevin (ILL). It should be recalled, however, that much of the impetus for the European advances was work done at smaller centers, e.g., Jülich, Germany (SANS, backreflection spectrometry), Saclay, France (SANS), Munich (guide tubes). Another key to the European success has been the development and use of cold neutron sources and associated guide halls to create instruments for ultra-high-resolution and high-sensitivity spectroscopy (currently providing energy resolutions as much as 5 orders of magnitude better than available in the United States), small-angle and medium-resolution diffraction, and a variety of other new scientific applications (e.g., ultra-cold neutrons). These sources and related new instrumentation represent the major advances in neutron-scattering capabilities since the mid-1970s, and their development continues to grow in both Europe and Japan. At present, there is only one cold neutron source in the United States (at Brookhaven National Laboratory) and one other is under development (at the National Bureau of Standards). Guide halls to improve the versatility and flexibility of cold or thermal neutron instruments currently do not exist in the United States. On the other hand, 60 percent of the neutron-scattering instruments at the ILL (16) are located in a large guide hall, and this fraction will rise when a new guide hall and cold source are completed over the next 2 years.

In Table 2 we list the characteristics of neutron instruments at the ILL (mainly brought on-line since the mid-1970s) that either do not exist in the United States or have characteristics of intensity or resolution that significantly surpass comparable instruments in this country. A number of instruments with comparable characteristics also exist (and in fact were developed) at other European centers, e.g., Jülich (Germany), Saclay (Orphèe) France.

The summary in Table 2 does not reflect the entire picture of new capital investment and advanced instrumentation development in Europe. For example, major efforts in the development and construction of focusing monochromators, polarizing devices, reflecting supermirrors, environmental control systems, and dedicated instruments for diffraction surveys using neutron cameras attest to the continuing highly organized efforts to build new and more efficient instruments at steady-state sources in Europe. Moreover, currently under development at the ILL is an improved D_2 cold source and a second D_2 cold source that will serve six new instruments to be installed in a new guide hall by 1985. Further, there is a new reactor center (Orphèe) at Saclay near Paris with two H_2 cold sources that will ultimately commission 20 new instruments for neutron-scattering and fundamental physics research. An expanded guide hall with 9 new instruments

TABLE 2 Unique Scattering Facilities at the Institut Laue-Langevin[a]

Instrument	Location	Wavelength/Energy/Wave-Vector Range	Areas of Application
IN-5 Multichopper spectrometer	Cold guide	10 μeV-30 meV/0-2.3 Å^{-1}	Low-energy excitation and quasi-elastic scattering in all materials
IN-6 Focusing time-of-flight spectrometer	Cold guide	70 μeV-30 meV/0-2.6 Å^{-1}	Quasi-elastic scattering and low-energy density of states for chemical and biological materials, catalysts, low-dimensional systems etc. (very high sensitivity)
IN-10 Backreflection spectrometer	Cold guide	0.3 μeV-100 μeV/0-2.6 Å^{-1}	Low-energy excitations (phonons, tunneling states, etc.) and diffusive process in solids and liquids
IN-11 Spin-echo spectrometer	Cold guide	25 neV-1 meV/0.02-2 Å^{-1}	Ultra-high-resolution spectroscopy of relaxation processes in polymers, biological matter, spin glasses, ferrofluids, etc.
IN-13 Backreflection spectrometer	Thermal guide	8 μeV-1 meV/0-6 Å^{-1}	Low-frequency dynamics, phase transitions, tunneling processes, diffusion in chemical materials, hydrogen in metals, polymers, etc.
D-5 Three-axis spectrometer with polarization analysis	Hot source	0.4-1.1 Å/50-400 meV	Polymerization analysis of magnetic-system studies of resonant nuclei possible
D-7 Diffuse-scattering spectrometer	Cold guide	$\geq$100 μeV/0-2.6 Å^{-1} polarization analysis	Static and dynamic aspects of short-range order in materials, paramagnetic scattering; uses polarized neutrons
D-9 Low-wavelength four-circle diffractometer	Hot source	0.4-0.8 Å	High-precision, medium-resolution studies of electron density, thermal parameters, and atomic disorder
D-11 Small-angle scattering instrument	Cold guide	5-20 Å/5 x 10^{-4}-0.3 Å^{-1}	The world's best neutron instrument for studying polymers and biological assemblages, microstructure, defects, pores in materials, magnetic clustering, etc.; exceeds state-of-the-art U.S. instruments in intensity and wave-vector range

D-16 High-resolution, low-wave-vector four-circle diffractometer	Cold guide	4-8 Å/0.05-2.5 Å^{-1}	Low-angle studies of micelles, biological membranes, surface slider
D-17 Low-angle diffractometer	Cold guide	4-10 Å/0.005-0.5 Å^{-1}	SANS and medium-resolution diffraction on macromolecules and biological systems
D-20 Two-axis diffractometer with curved PSD	Thermal beam	1-3 Å/0-7 Å^{-1}	High-sensitivity, rapid-powder, liquid and glass diffraction, real-time structure studies
IN 1B Hot source three-axis spectrometer	Hot-source beam	0.4-1.5 Å/30-400 meV	High-energy excitations in molecular solids, magnetic materials, metal hydrides, etc.
IN 14 Wide-range cold-neutron triple axis[b]	Cold guide	0-15 meV/0-4 Å^{-1}	Dynamics of structural phase transitions, critical scattering, etc.
IN 15 High-resolution spin-echo spectrometer[b]	Cold guide	≥4 neV/0.01-0.3 Å	Dynamics of macromolecular systems
DB 21 Dedicated small-angle diffractometer for biology[b]	Cold guide	5-10 Å/0-1 Å^{-1}	High-sensitivity, low-resolution studies of large biological structures (~0.5-mm crystal sizes)
Ultra-high-resolution diffractometer	Cold guide	4-10 Å/0-3 Å^{-1}	Crystallography of materials with large volume unit cells

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[a] Instruments that either do not exist in the United States or whose characteristics are not fully matched in this country. In may cases, analogous instruments exist or are being developed at other European centers, e.g., Orphée, Jülich, Riso.

[b] Under development at new cold source.

is also under construction at the KFA Research Reactor in Jülich. Finally, the Japanese government has approved funding for the complete modernization of the JAERI III reactor at a cost of ~$150 million, including a replacement of the vessel, an upgraded fuel and beam-tube arrangement, and installation of a large cold source and guide hall.

The total current operating expenditures for neutron scattering at research reactors in Western Europe is about $80 million/year (in fiscal year 1983 dollars) including associated reactor operation costs, roughly triple the U.S. effort. An order-of-magnitude difference emerges when one compares capital investment for new spectrometer development and construction efforts. Aside from recent new reactor construction (Saclay) and modification (Berlin), currently ~$45 million worth of new or advanced neutron-scattering instruments and guide halls are either being commissioned or under development, primarily in France and West Germany but also in Sweden and Denmark. There is also a proposal for a major redevelopment of the Munich university research reactor to provide a new advanced center for neutron-scattering research.

The consequences of this investment gap over the past decade between European and U.S. research reactors is being increasingly felt in our inability to compete in many areas of new science related to high-resolution neutron spectroscopy, small- and medium-angle diffraction, and diffuse scattering, for example. Further, the high degree of flexibility and efficiency afforded by the development of cold sources, guide-tube technology, and beam-focusing techniques has not been pursued in the United States. Fortunately, the major U.S. research reactors are still world class in terms of available thermal-neutron-beam intensities, and there are immediate opportunities to achieve a competitive status in advanced instrumentation for both cold and thermal neutron scattering, which will be outlined in Chapter 6.

PULSED NEUTRON SOURCES

The current U.S. position in pulsed neutron research and development is better in relative terms with respect to foreign competitors than is the case for steady-state sources. For example, the intense pulsed neutron source at Argonne National Laboratory is, for the present, the highest-intensity facility in the world, and the WNR/PSR is scheduled to provide by 1987 an order-of-magnitude increase in intensity for pulsed-neutron experiments. However, developments abroad make current comparisons highly misleading. For example, the SNS advanced spallation source under construction at the Rutherford Laboratory is scheduled to be brought on line by the end of 1984, with neutron intensities 2-3 times the current IPNS performance and will ultimately (by 1986) generate a current of 200 μA of 800-MeV protons on a spallation target, thus providing a peak thermal flux of 5×10^{15} neutrons/cm^2-sec at a 50-Hz repetition rate, roughly twice the total intensity of the scheduled WNR/PSR source. This facility will ultimately have a complement of at least 15 neutron-scattering instruments, providing unmatched flexibility. Moreover, the Japanese, who have developed a modest-flux facility at Tsukuba with an impressive array of instruments, are also funding a planning and design study for a major new pulsed source (cost ~$100 million in fiscal year 1983 dollars) that would slightly exceed the characteristics of the SNS.

Perhaps of greatest potential impact on the long-term development of pulsed neutron sources, is the extensive study and design effort under way at the KFA in Jülich, West Germany. This major planning project with a budget of ~$6 million/year is aimed at the possible ultimate construction of a pulsed spallation source with an ~10^{17} neutrons/cm^2-sec peak flux and a time-averaged flux exceeding 10^{14} neutrons/cm^2-sec. The potential cost of this facility (~$300 million to $400 million capital, ~$30 million/year operating) of course raises large scientific and political questions in the European community and will, at the very least, require a broad multidisciplinary base of support. The development of a source with these flux characteristics is perceived necessary by the German group in order to match or surpass the capabilities of modern high-flux reactors for low-energy neutron research and at the same time to exploit fully the new opportunities offered by pulsed sources, particularly for high-energy (>100-meV) neutron scattering. The study also includes a major effort to develop concepts and designs for a new generation of scattering instruments. Active efforts in new instrument designs are also a major part of ongoing activities at the Rutherford Laboratories in Great Britain, in Japan, and at the Argonne National Laboratory (ANL) and the Los Alamos National Laboratory (LANL) pulsed sources. The two U.S. pulsed neutron efforts currently have a combined budget for source operations and scientific costs of about $10 million/year.[2] While this amounts to about 40 percent of the total U.S. neutron-scattering funding, it still does not, for example, allow full-time operation of the IPNS source. In addition, this funding level provides only marginal discretionary resources for the development of new instrument or source concepts. Again, as for U.S. research reactors, there are important opportunities for future pulsed-source development and research activities, which will be outlined in a later section.

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[2] This figure assumes $2 million as the share of scientific and facility operating expenses provided at the WNR by the Office of Military Applications (OMA) of Department of Energy and discretionary LANL funds. The apportionment of funds provided by OMA for the development and scientific use of the WNR/PSR between nuclear or weapons-related research and materials-science applications is a complicating factor in the exact assessment of current neutron-scattering research funding but does not substantially affect the comparisons of U.S. and Western European funding included in this report.

5. RECENT NEUTRON-SCATTERING RESEARCH IN THE UNITED STATES; COMPARISONS WITH EUROPE

In this chapter we present selected summaries of important research areas and accomplishments during the past 6 years. These summaries have been coordinated by experts on the panel in the appropriate scientific disciplines involved and reviewed by the panel as a whole. The focus is generally on U.S. neutron-scattering work, except in cases where activity has been dominated by special capabilities abroad (e.g., high-resolution spectroscopy, broad areas of polymer and chemical research). Where the work involves new areas of scientific applications of neutrons that have evolved recently (e.g., polymer and materials science, biology, chemical spectroscopy), we have tried to provide more background to explain the special role of neutrons in these cases. An attempt has also been made to point out both new directions in science and examples of broad areas where instrumentation at U.S. neutron sources does not allow critical scientific opportunities to be pursued.

CONDENSED-MATTER PHYSICS

Physicists were the first scientists to exploit the unique properties of the neutron in studying condensed matter, and after 30 years of intense activity the level of interest and vitality of the field are undiminished. In the following paragraphs we survey the contributions that neutron scattering has made to the various subfields.

It is worth reflecting that most of the results discussed represent not only significant advances in our understanding of the physics of the materials but that neutron scattering provided unique information not available from other known techniques. Two examples, discussed more fully in subsequent sections, illustrate this particularly well. The first is the development of magnetic order in superconductors, where a series of key discoveries beginning in the late 1970s and involving a close interplay between imaginative materials synthesis and neutron-scattering studies have caused the simple dictum that "superconductivity and magnetism don't mix" to be greatly revised. In this case although thermodynamic and magnetic measurements suggested the occurrence of unusual phenomena in those new materials, neutron scattering was essential to establish its nature.

A second example is provided by ongoing recent studies of the effect of disorder on the collective behavior of condensed-matter systems. Major conceptual difficulties have arisen in recent years as to the behavior of a simple magnetic model system when placed in a magnetic field that varies randomly in direction from site to site. Although the model has attracted much interest as a prototype of real physical disorder, the production of such a random field on an atomic scale is experimentally not possible. However, as it turns out, the application of a uniform magnetic field to a dilute random antiferromagnet produces a random antiferromagnetic internal field and a physical situation that simulates the ideal theoretical model. Neutron-scattering measurements on such systems are now providing the critical experimental tests of our understanding of simple random systems.

Magnetic Systems

The determination of magnetic structures was one of the first and most important applications of neutron diffraction. While many of the interesting magnetic structures of simple materials have now been determined, the ability to make these determinations on new materials will be essential for the indefinite future as long as new materials are developed. Most magnetic structures have been determined at medium- to low-flux sources using a two-axis diffractometer, but for very complex structures (Nd, PrAg, TmS), or for fine structural details (MnP), the polarization analysis technique can be extremely valuable. Use of this technique has been limited because there are only a few spectrometers in the world equipped for these measurements.

Amorphous ferromagnets have enormous potential value in commercial applications, and neutron scattering has been used in a variety of ways to understand these materials on a microscopic basis. Diffuse scattering measurements have been used to obtain the radial distribution functions that describe the basic structure, inelastic neutron-scattering studies have given details of the spin dynamics, and small-angle scattering has been used to study the microstructure. Neutron experiments on these materials have been carried out worldwide. The advantage of using polarized neutrons has not yet been fully exploited in these studies. Another class of materials that has attracted great experimental and theoretical interest in recent years is that group of rare-earth materials in which the rare-earth ion apparently has a fractional valence—the intermediate- or mixed-valence materials. These materials do not show magnetic order, and the neutron-scattering spectra show a broad quasi-elastic line with an energy width in the range from 10 to 100 meV. The shape of this line is consistent with a fast (10^{-13} sec) relaxation process of the rare-earth spins. Actinides frequently show many characteristics of the unstable 4f moment systems. In the rock salt uranium compounds, for example, experiments have shown that, even though the systems order magnetically, spin waves need not exist. A combination of x-ray photoemission spectroscopy (XPS) and neutron spectroscopy suggests that the unusual damping is caused by strong 5f-6d electron interactions. Both critical and inelastic magnetic scattering has contributed greatly to our understanding of the solid-state physics of the last row of the periodic table. In another kind of experiment, polarized neutrons have been used to measure the induced magnetic form factor in order to gain a better understanding of the behavior of the f electrons in these materials. In general, these form factors are not dramatically different from free-ion form factors for integral valence ions. Interesting exceptions are CeSn and CePd, where evidence of some 5d polarization is found at low temperatures.

As an example of the subtlety of magnetic systems and of the continuing long-term need for state-of-the-art neutron-scattering facilities, it should be noted that new and exciting facts about the most studied of all magnetic materials, Cr, Fe, and Ni, are still being discovered through neutron-scattering experiments. Recent polarization analysis experiments of the diffuse scattering from Fe and Ni in the paramagnetic phase have revealed short-range magnetic order extending well above T_c. In another type of polarized-beam experiment, the appearance of "forbidden" magnons in Ni well below T_c indicates a deviation in the local and bulk magnetization directions. Commensurate diffuse excitations have been observed in the incommensurate spin-density wave state of Cr metal. These excitations were completely unexpected and are not yet understood. All of these experiments give valuable insights into the fundamental nature of the magnetic behavior of these important metals.

Practically all areas of magnetic research would benefit from more and improved neutron polarization analysis spectrometers. Higher source fluxes and improved polarizers are both important for the growth of this technique. Fortunately, recent advances in this country and Europe toward better polarizers have been made. Pulsed-neutron sources show promise for enabling inelastic magnetic scattering at high-energy transfers. For example, recent measurements have already extended the spin-wave spectrum in Fe to higher values than previously possible, and such sources promise new opportunities to locate the single-particle (Stoner) continuum. The lack of very-high-resolution instruments, such as a neutron-spin-echo spectrometer, has limited the U.S. research in important areas, such as the relaxation effects in spin glasses.

Phase Transition

From its inception, neutron scattering has made important contributions to the field of phase transitions and critical phenomena. Not surprisingly, this has continued to be the case for the past 6 years. Phase transitions occur in a wide variety of systems so that the work discussed in this section will overlap with results presented in most of the other sections. There has been an interesting evolution in the class of materials and the types of problems being pursued. Initial work, especially in the period 1965 to 1975, concentrated on prototypical phase transitions in model systems. Examples include soft modes in ferroelectrics and in other systems exhibiting structural transitions such as $SrTiO_3$, ordering in binary alloys such as CuZn, and magnetic transitions in simple magnets such as $RbMnF_3$, K_2NiF_4, Fe, and Ni. These experiments were invaluable in elucidating the basic principles governing critical phenomena.

As a result of these early studies and of important advances in theoretical understanding, it has proven possible to address much more complicated issues. Recent neutron work has concentrated on the phase-transition behavior of more exotic systems. Indeed a number of the more interesting experiments involve issues that were barely conceived of at the time of the previous NAS report. Examples include random field effects, spin-Peierls transitions, devil's staircase phenomena in incommensurate systems, re-entrant superconductivity, re-entrant spin-glass behavior, and other effects originating from competing interactions. In each case neutron-scattering experiments have provided a key to understanding the basic physics underlying these phase transitions. It is also interesting to note that with a few important exceptions, the crucial experiments have involved conventional elastic and inelastic neutron-scattering (including SANS) techniques. The most serious limitation typically has been sample size or, equivalently, neutron flux. In many cases major improvements in momentum or energy resolution, or both, currently available or under development in Europe, will be of increasing importance. In this brief report, it is impossible to survey all the beautiful experiments that have been performed in the last 6 years. We therefore limit ourselves to a few representative samples.

The effects of randomness, especially in systems with competing interactions, are now being extensively explored. Particularly dramatic effects are observed in spin systems with random magnetic fields, that is, magnetic fields with zero average value but nonzero variance. Neutron experiments in both the United States and Europe have verified that a uniform field applied to a random antiferromagnet generates a random staggered magnetic field; this makes possible a systematic study of the phenomena. High-resolution experiments on both two- and three-dimensional systems have revealed that long-range magnetic order is not attained in the presence of a weak random field and that instead one sees with decreasing temperature a continuous evolution from the paramagnetic state to a frozen microdomain state. Such random field effects are undoubtedly important in a range of other physical systems, including random-anisotropy rare-earth amorphous alloys.

Spin glasses have been the subject of intense experimental and theoretical study in recent years, and neutron techniques have contributed greatly to our understanding of these materials. In Europe, a combination of the neutron-spin-echo and polarization-analysis techniques have been used to measure the time-dependent spin-correlation function of Cu-Mn alloys over a time range from 10^{-12} to 10^{-9} sec. In the United States, elastic polarization analysis measurements on single crystals of Cu-Mn have demonstrated strong short-range magnetic correlations associated with short-range nuclear order. Exotic effects are also observed in alloys with competing ferromagnetic and antiferromagnetic interactions. With increasing concentration of antiferromagnetic bonds one observes an evolution from ferromagnetism to spin-glass behavior. For ferromagnets with concentrations near the crossover point one sees "re-entrant behavior," that is, with decreasing temperature the system evolves from a paramagnet to a ferromagnet to a spin glass. The spin-wave frequency appears to soften at both the paramagnetic-ferromagnetic and ferromagnetic-spin glass transitions. In addition, unusual diffuse scattering is observed in the re-entrant phase, presumably originating from residual microdomains of the ferromagnetic network. These effects have been seen in such systems as Fe_xCr_{1-x}, Fe_xNi_{1-x}, PbAl, and FeMnPC. This is still an active and rather controversial area of research. It should be noted that the most precise experiments have been performed at Grenoble utilizing the small-angle scattering and high-energy resolution spectrometers. Systems with competing anisotropies rather than competing interactions have also been studied. Here again one observes new magnetic states whose basic structures and excitations could only be elucidated with neutrons.

The study of phase transformations and other highly cooperative phenomena is perhaps the most challenging and subtle that condensed-matter physics has to offer. At the same time, fresh ways of thinking about such systems have greatly expanded our ability to understand such systems and suggested subjects for new studies. Such systems are very often magnetic because of their relative freedom from complicating extraneous interactions. As in the past, neutrons will continue to provide an indispensible tool for such studies.

New Materials and Phenomena

The unique capabilities of neutron studies are readily apparent in the study of the coexistence of magnetic and superconducting long-range order, which was discovered ("engineered" is a better term) in the late 1970s. The phenomenon of superconductivity is quite tolerant of large concentrations of impurity atoms, so long as they are not magnetic in character, but is quickly destroyed by small concentrations of magnetic impurities. This peculiar fact was readily explained by the Bardeen, Cooper, and Schrieffer (BCS) theory, which showed how superconductivity can arise from a binding of pairs of electrons that travel in time-reversed orbits. Magnetic impurities that do not respect time-reversal symmetry destroy the pairing, whereas chemical impurities simply scatter the electrons into new time-reversed orbits leaving the superconductivity intact. The early studies of the magnetic suppression of superconductivity were carried out on simple binary alloys in which magnetic impurity atoms were substituted randomly into the lattice of the superconducting metal. Reasoning that a more stringent test of coexistence would result if the electrons responsible for the superconductivity could be effectively separated from those electrons responsible for the magnetism, new studies were undertaken on more complex ternary systems, in which the magnetic atoms are separated from the atoms responsible for the superconductivity by a barrier of inert atoms, preventing strong interaction between the two.

In the case of materials such as $DyMo_6S_8$, heat-capacity measurements showed the presence of a new kind of ordering occurring below the temperature of the onset of superconductivity. Neutron-diffraction studies were necessary to establish the nature of the ordering, which was found to be simple antiferromagnetism in which planes of atoms with magnetic moments up and down alternate. The superconductivity is not destroyed, proving that superconductivity and antiferromagnetism can simultaneously coexist at the same temperature. In materials such as $ErRh_4B_4$, neutron-scattering studies have shown that ferromagnetic arrangement of magnetic moments arises at temperatures below that at which the sample becomes superconducting and that in the process the sample regains its normal conductivity. Thus, superconductivity and ferromagnetism can exist in the same material but apparently cannot coexist at the same temperature. Further insight into the nature of the competition between magnetism and superconductivity has recently come from studies of small-angle neutron scattering, which reveal that even when the ferromagnetic state is marginally unstable, an entirely new type of order, taking the form of a long-wavelength oscillating magnetic disturbance can coexist with the superconducting state. These findings may have far-reaching implications for the directions of future research in superconductivity.

Graphite is a prime example of a layered structure composed, in this case, of covalently bound sheets of carbon atoms with adjacent sheets held together more loosely by van der Waals forces. New compounds with unusual properties can be prepared by inserting, for example, alkali metal atoms between the graphite sheets. Among the fascinating and incompletely understood aspects of these resulting graphite intercalation compounds (GIC) is the structure of the inserted atoms. Neutron-scattering studies have elucidated the nature of the stacking of adjacent metal layers and have shown that at high temperatures the ordering is liquidlike. Unsaturated materials, prepared with low-metal-vapor pressure, have metal atoms inserted between every nth graphite layer, where n is a simple integer. This phenomenon is known as staging. Recent neutron-scattering experiments under hydrostatic pressure have revealed a new fractional staging sequence, related to the n = 3 stage by particle-hole symmetry, whose existence helps to decide between competing theories of the staging phenomenon. A recent first study of the dynamic structure factor and diffusion processes in higher-stage metal-graphite compounds has only been possible by joint U.S.-ILL experiments using high-intensity and high-resolution spectrometers at the ILL.

Models of one-dimensional (1-D) magnetic systems show in addition to linear spin-wave excitations, localized large-amplitude excitations that preserve their integrity as they move along a chain. It is expected that these excitations, called solitons, exist in real materials, and considerable effort has been made to observe them by neutron scattering. Both planar 1-D ferromagnets and antiferromagnets in external magnetic fields are expected to have soliton excitations, although the effects are more difficult to interpret in the ferromagnetic case, where neutron measurements in CsNiF are still controversial. Soliton effects have been successfully observed in the nearly classical S = 5/2 antiferromagnet, TMMC, by a group at ILL. In $CsCoCl_3$ ($S = 1/2$), which is an easy-axis antiferromagnet, soliton effects are expected even in the absence of an external magnetic field, and they have been seen by neutron scattering. The longitudinal excitations can be thought of as Doppler-shifted quasi-elastic scattering from moving domain walls (solitons), whereas the transverse excitations involve the creation of domain wall pairs.

A new class of materials that has attracted considerable interest in the past few years are incommensurate systems, in which two subsystems with mutually incompatible translational symmetry coexist. For example, if the instabilities associated with structural phase transformations involve competition between forces of various ranges, the resulting distortion waves may be incommensurate with the underlying lattice. This mechanism was first identified with charge-density wave (CDW) formation in metals, and there have been several recent studies of CDW transformations in quasi-1-D metals such as potassium cyanoplatinate (KCP) and TTF-TCNQ. A related transition, known as a spin-Peierls transition, may occur in $S = 1/2$ magnetic chains. The transition, which is predicted to be a simple dimerization for nearest-neighbor interactions, has in fact been observed in two different quasi-1-D magnets. Incommensurate phase transformations have also been discovered in insulators, a particularly clean example being potassium selenate (K_2SeO_4), where a low-frequency phonon with an incommensurate wave vector has been observed by neutron studies above the critical temperature. Elementary theory shows that this system has a two-component order parameter and should have critical properties identical to the XY ferromagnet. This has been verified, in part, with neutron studies. The phenomenon of "locking in," whereby an initially incommensurate lattice distortion becomes pinned at a commensurate value was first observed by neutron studies, and recently an example of electric-field-induced lock-in transformation has been found in the ferroelectric thiourea.

Crystal Dynamics

The frequencies and displacement patterns of the vibrational modes provide the most direct available insight concerning the strength and range of interatomic forces in solids. Optical and electron tunneling spectroscopies provide valuable but limited information concerning vibrational properties. Inelastic neutron scattering has proven the most reliable and complete tool for investigating phonon dispersion relations in solids. The techniques, using triple-axis spectrometers at moderately high-flux reactors are by now classical. They will continue to fulfill a vital need so long as the understanding of the forces in increasingly sophisticated new materials challenge condensed-matter scientists. The interatomic forces in metals are profoundly modified by screening from the conduction electrons. In the case of d-electron metals these screening effects can be seen as more or less sharp anomalous features in the phonon dispersion and provide exacting tests of state-of-the-art electronic-band-structure calculations. Such tests have been provided in recent years through detailed neutron-scattering studies of various transition metals, alloys, and transition metal carbides. Metals with flat or otherwise well-nested portions of Fermi surface can show giant Kohn anomalies, which are precursors of charge-density wave instabilities such as the Peierls transformation discussed above. Of the various quasi one- and two-dimensional systems studied extensively with neutrons, the 1-D metal (KCP) is the most spectacular. Phonon linewidth effects are a potential rich aspect of e-p interaction largely unexplored with neutrons owing to lack of energy resolution. Ideas for high-resolution momentum focusing instruments exist but would require higher-flux sources to achieve their full potential.

The presence of a weakly coupled incommensurate charge- or mass-density wave in an otherwise periodic structure gives rise to new gapless excitations, which correspond to relative translations of the density wave. Such modes, sometimes called phasons, differ from true acoustic modes, not only in the nature of the atomic displacements involved but also in the fact that they become overdamped as their wave vector goes to zero, making them difficult to study with optical probes. Such modes have now been seen in several incommensurate systems. In one of these, Hg_xAsF_6, incommensurate mercury chains behave independently at high temperatures, and neutron studies show that at short wavelengths the dynamics are those of a 1-D harmonic fluid. Inelastic neutron-scattering studies have measured the dispersion of longitudinal elastic waves in graphite intercalated with various donor and acceptor atoms. These measured dispersion curves provide direct information on the magnitude and range of the interlayer forces. For example, the graphite-alkali atom coupling is greater than the normal graphite-graphite coupling in pristine graphite, whereas the reverse is true for the acceptor intercalant, $FeCl_3$. Results also scale according to the intercalant areal density, suggesting that every intercalant atom, but not every graphite atom, contributes to the interplanar stiffness. Although of great interest, from the viewpoint of 2-D physics, it has proven difficult to carry out similarly detailed studies of phonons propagating within the intercalant layers, because of sample size restrictions. This is one example of a limitation imposed by present reactor fluxes.

Defect Systems

To characterize completely the dynamics of hydrogen dissolved in metals requires measurements over a wide range of energy transfer. The diffusive motions result in quasi-elastic scattering, requiring instruments with energy resolution down to 1 μeV. This field of research has been active in Europe using the very high resolution available with neutron backscattering spectrometers. The low-energy vibrational aspects are coupled to the acoustic phonons of the host lattice and have been studied throughout the world using triple-axis spectrometers. The optic modes, or localized modes for dilute hydrides, have been measured by both triple-axis and time-of-flight techniques. The Japanese have demonstrated the value of a pulsed neutron source by measuring local vibrational spectra up to 800 meV. The large incoherent cross section of H makes it possible to perform scattering measurements on dilute solutions, and recent efforts in the United States have extended these spectroscopic studies to samples in the ~0.1 percent H regime where hydrogen embrittlement occurs. These improvements have also provided unique information on the local environment and bonding potentials of hydrogen trapped by impurities in metals. The study of diffusive motions is also important in fast ion conductors. Here the time scale is somewhat shorter than is the case for hydrogen in metals so that triple-axis spectrometers can be employed. Such experiments have been performed both in the United States (on LiAl, for example), and in Europe (on $SrCl_2$, for example).

The introduction of complex defects with internal degrees of freedom into a crystal lattice produces a variety of interesting effects. Resonant hybridization of the defect states and phonon modes of matching symmetry and energy have been clearly observed in neutron-scattering measurements of dilute CN^- impurities in KCl. In the mixed-crystal system $(KCN)_x(KBr)_{1-x}$, the CN^- ions freeze into a random distribution of orientations as the temperature is lowered, producing an orientational glass state analogous to spin glasses. This state was discovered through the observation of diffuse elastic neutron scattering.

The greatest shortcoming of the U.S. efforts in the study of defect systems is the lack of very-high-resolution spectrometers for studying quasi-elastic scattering and tunneling phenomena. The backscattering instruments in Europe have given them unchallenged leadership in such fields as hydrogen diffusion.

Surfaces and Overlayers

At the time of the NAS report on Neutron Research on Condensed Matter in 1977, a few demonstration neutron experiments on surface phenomena had been reported. As we shall discuss in this section, this has now developed into a major area of research with active programs at many major facilities in the United States and Western Europe. It seems clear that this field will continue to grow, and, indeed, certain of the problems (e.g., high-energy spectroscopy) are well matched to pulsed neutron sources, so that one can expect major activity at the new pulsed sources as they come on-line. Because neutron source intensities are relatively low, and further since neutrons interact weakly with matter, one might expect that surface signals would be undetectably low. This is indeed the case for virtually all single-crystal surface experiments. However, there is a variety of microcrystalline substrates, most notably exfoliated graphite, with surface areas as large as 40 m^2 g^{-1}. Thus for a 2.5-cm^3 sample the illuminated surface area may be as large as 300 m^2. In favorable cases, it is then possible to separate out scattering events that originate from physisorbed or chemisorbed overlayers from the bulk scattering. Elastic, quasi-elastic, and inelastic neutron-scattering studies of surface overlayers have now all been reported. The most detailed studies to date have been for rare-gas atoms, diatomic molecules, and hydrocarbons physisorbed on graphite. Some experiments in thick films and on co-existing bulk and film phases have also been reported. They involve primarily powder diffraction with an energy analyzer to eliminate inelastic events or else inelastic scattering using triple-axis or time-of-flight techniques. In most cases, the essential limitation has been absolute signal levels. Thus, an increase in neutron flux by an order of magnitude would have a fundamental impact on this field.

Elastic-scattering experiments yield information on the overlayer structures and transitions. The first such studies were on atoms and diatomic molecules physisorbed on graphite; species studied with neutrons include H_2, D_2,

^{4}He, ^{3}He, Ar, and N_2 on graphite. All of these exhibit triangular structures with a lattice constant either commensurate or incommensurate with respect to the graphite substrate. By changing the coverage, the temperature, or both, it has been possible to study both commensurate-incommensurate and melting transitions. The structures of the various phases have been accurately determined, but because of flux limitations, only qualitative information has been obtained on the details of the phase transitions.

Systems exhibiting more complicated phases and phase transitions have also been studied with elastic neutron-diffraction techniques. These include O_2, CF_4, N_2, C_2D_6 (ethane), and C_5D_{12} (butane) on graphite as well as C_5D_{12} (neopentane) on TiO_2. Bilayers of O_2 on graphite exhibit an antiferromagnetic transition at 12 K, and evidence for the concomitant superlattice peak has been obtained. For nonspherical molecules the structures may be quite complicated; the unit cell may be a low-symmetry parallelogram, and the molecules may be tilted with respect to the surface. Such structures have been solved for butane and N_2O_2 on graphite. The butane system also appears to exhibit quite interesting melting behavior. Very recently, diffraction studies have been reported for CD_4 and Ar on $NiCl_4$. It has also been realized that these physisorbed systems may exhibit co-existing bulk and film phases with reversible transitions between the surface and bulk structures. Such effects have now been seen directly with neutrons for C_2D_4 on graphite.

Of course, one of the salient advantages of neutrons over other scattering techniques is the ability to study dynamics in the range of typically 0.1 to 100 meV. So far, only a limited number of inelastic-scattering experiments have been carried out on surface systems. Interesting results have been obtained in both the United States and Europe for hydrogen chemisorbed on metallic surfaces such as Raney Ni, platinum, and palladium blacks. These are all of fundamental interest in the field of catalysis; vibrational excitations are observed whose frequencies match well to the results of model calculations. Collective effects have also been studied using triple-axis techniques. For example, the phonon density of states for monolayer argon on graphite has been obtained; the in-plane results can be reasonably well described at low temperatures by a two-dimensional roton. Finally, a limited number of quasi-elastic experiments probing surface diffusion have been performed. Particularly interesting behavior has been observed for CH_4 on graphite near melting.

Clearly, this is a vigorous, rapidly expanding field in neutron scattering. We expect that an increasing number of experiments will be performed on high-surface-area substrates, especially those relevant to catalysis. Increased flux would greatly facilitate these studies.

Liquids and Glasses

Neutron-scattering techniques have provided the most detailed and complete experimental results on the structure and dynamics of isotropic systems in both the liquid and amorphous states. These systems present one of the outstanding challenges in statistical physics, since, in contrast to solids, there is no available first-order theory in terms of independent quasi-particles such as magnons and phonons. Indeed, progress has only been possibly by detailed comparison of the results of neutron scattering with the results of molecular-dynamics simulations, a technique that has so far been more successful for liquids than for glasses or amorphous solids. Nevertheless, real progress has been made in recent years in a fundamental understanding of the statistical physics of these systems, particularly in the use of kinetic theories. An area in which the above considerations do not apply is that of the quantum fluids ^{3}He and ^{4}He, where neutron scattering has been used to study the detailed predictions of available theories. In the following, we describe some examples of results over the past 6 years that illustrate the power of the technique and the progress being made.

Quantum Fluids

Recent neutron inelastic scattering studies have revealed the elementary excitation spectrum of ^{3}He for the first time, stimulating intense theoretical effort and greatly increased understanding of the underlying physics of Fermi liquids. In view of the extremely high neutron absorption cross section of ^{3}He, these experiments represent an unrivaled tour de force of experimental techniques. Future research in this area will provide new insights into the dynamics and quasi-particle excitations in ^{3}He, ^{4}He, and mixtures of the two isotopes, leading to new theoretical advances in the understanding of quantum liquids. These studies will be greatly enhanced by the availability of intense beams of epithermal neutrons from pulsed spallation sources.

An outstanding problem in quantum statistical mechanics has been the existence and properties of a Bose condensate in superfluid ^{4}He and the nature of the momentum distribution in both normal and superfluid He. Recent neutron-diffraction results have led to very precise estimates of the condensate fraction in superfluid ^{4}He, while high momentum transfer experiments on normal and superfluid ^{4}He using epithermal neutrons show promise of giving very detailed measurements of the momentum density distribution, but again increased fluxes are needed to provide the necessary resolution and sensitivity.

Classical Liquids

One of the outstanding results from neutron-scattering studies of classical liquids in recent years has been the measurement of the density dependence of both the static and dynamic structure factors in dense krypton gas. These results give direct information about the nature and magnitude of the three-particle correlations in this system for comparison with the predictions of statistical physics, and thus promise much better models for these many-body effects. Additional progress can be expected as higher-intensity time-of-flight instruments and pulsed sources become available for measurements of the structure and dynamics of simple fluids.

Recent results from neutron-scattering studies of liquid crystals at reactors in Europe have identified the existence of hydrodynamic instabilities and time-dependent states and phase diagrams with multicritical properties in liquid crystals. Further progress in this area can be expected, especially in the area of novel magnetic fluids with liquid-crystal-like ordering.

Glasses and Amorphous Solids

The principal achievements in the fundamental understanding of this important class of materials has come from detailed measurements of the static structure factor by x-ray and neutron scattering, combined with the detailed information about local order derived from extended x-ray absorption fine structure (EXAFS). In particular, the use of isotopic substitution methods for neutron diffraction, combined with x-ray diffraction results, has led to direct determination of the partial structure factors for several glasses. This has provided a better understanding of the short-range structure and chemical ordering in a wide variety of glasses. However, much work remains to be done both on the intermediate-range structure and on the recrystallization process (using small-angle neutron scattering). Progress in this area requires exceptionally high-quality data extending over the widest possible range of momentum transfers, placing severe demands on instrumentation. The development of intense pulsed spallation sources will greatly enhance detailed analysis of interatomic arrangements in these systems.

To date, little work has been done on the dynamic properties of glasses, at least partially because of the lack of adequate theoretical models. Nonetheless, important results have been obtained on reasonably simple metallic glasses ($Ca_{10}Mg_{30}Zn_{30}$) and compared with computer simulation studies done using pair potentials derived from pseudopotential theory. These experiments have shown that the pair potentials used in the simulations give a good representation of the dynamics and have led to increased efforts to derive better potentials for semiconductors and insulators. New predictions concerning phonon density of states in amorphous materials based on the fractal nature of self-similar structures need to be explored by neutron-scattering experiments. As these and other efforts continue, neutron scattering will unquestionably provide the ultimate test of most theoretical models, since it provides data over a uniquely wide range of energy and momentum.

NEUTRON OPTICS

A range of phenomena similar or analogous to those of classical optics is exhibited by slow neutrons. During the past 6 years considerable interest has been generated in this field from the point of view of fundamental physics. This has been due largely to the successful application of the perfect silicon-crystal interferometer to neutron experiments and to the increased availability of more intense sources of long-wavelength neutrons.

Neutron optical ideas and techniques play an important role in all aspects of neutron-scattering technology, in particular in the extraction, filtering, and monochromatization of beams. Substantial advances have been made in recent years in focusing monochromators, collimation systems, multilayer mirrors, and beam guides. We will not attempt to enumerate these advances in the application of neutron optics to neutron scattering generally but will instead discuss the variety of interesting experiments that have made an impact on our understanding of basic quantum-mechanical phenomena.

The Bonse-Hart perfect-crystal interferometer was first shown to work for neutrons by H. Rauch, W. Treimer, and

U. Bonse at a small reactor in Vienna, Austria, in 1974. It is topologically analogous to the Mach-Zehnder interferometer of classical optics. It consists of three identical perfect silicon-crystal slabs, cut perpendicular to a set of strongly reflecting lattice planes from a single monolithic crystal. The incident beam is coherently split and recombined by Bragg reflection. Alternative two- and three- crystal geometries have been employed successfully. In recent years, these devices have also been used at synchrotron radiation sources to measure the dispersion correction f' close to the x-ray absorption edges. These measurements of the real part of the forward-scattering amplitude directly reflect the EXAFS of the absorption spectrum.

In the neutron case, these devices have allowed the observation of quantum-mechanical interference phenomena on a macroscopic scale. They are extremely sensitive to very small potentials acting on the neutrons. The current level of sensitivity approaches 10^{-12} eV. Interference effects induced by the gravitational field of the Earth have been observed. In fact, the much smaller phase shifts due to the Earth's rotation (a quantum-mechanical analog of the famous Michelson-Gale-Pearson optical experiment) have also been observed. These experiments are the first tests of the principle of equivalence in the quantum limit. The first direct observation of the prediction that the operator for rotation through 2π rad causes a reversal of sign of the wave function for a fermion was also done with this device. A complete list of the experiments utilizing thermal neutron interferometry is now quite long. It includes the observation of the coherent superposition of spin states, study of the charge dependence of the four-body nuclear interaction, search for quaternions in quantum mechanics, observation of the neutron analog of the Fizeau effect, search for nonlinear terms in the Schrödinger equation, measurement of the longitudinal coherence length of the neutron, and a search for a neutron Aharonov-Bohm effect. Interference in spin space, using the nuclear magnetic resonance-Ramsey technique, has recently been used to observe optical rotation via parity-violating weak interactions. While the perfect crystal interferometer utilizes interference by amplitude division, interferometers based on division of the wave front have also been successfully employed in recent years. In order to achieve a reasonable beam separation, these devices all utilize long-wavelength neutrons ($\lambda \gtrsim 20$ Å) obtained from a cold source. The neutron Fizeau experiment was carried out using this type of interferometer. Many of the well-known optical phenomena have now been observed with neutrons, including two-slit interference (Young's experiment), operation of Fresnel zone plate lenses, thin-film multiple interferences, and diffraction by a straight edge. Cold neutrons have also been essential in recent experiments on the neutron lifetime and continuing searches for the electric dipole moment (EDM) of the neutron. Novel methods for producing ultra-cold neutrons involving Doppler-shifted Bragg scattering and downscattering in liquid helium have been demonstrated successfully in the last several years.

At present, fundamental physics utilizing neutron optical techniques is primarily carried out at four places: the University of Munich, the Institut Laue-Langevin in Grenoble, the University of Missouri, and the Massachusetts Institute of Technology. It is difficult to predict the future directions that this field will take. However, there are various fundamental neutron-optics-related experiments currently in progress and others on the immediate horizon. It is likely that continuously higher-precision searches for a neutron EDM will be pursued using ultra-cold neutrons. The measurement of the energy dependence of neutron-scattering lengths using various interferometers will be pursued as these data become necessary for scattering experiments using epithermal neutrons from pulsed spallation sources. A Michelson-Morley experiment with neutrons should be done. Very small effects, such as the coupling of the neutron spin to the curvature of space-time (owing to the presence of the Earth), are in principle detectable with significantly larger interferometers, having linear dimensions of a meter or so. Neutron trajectory and effective mass experiments in dynamically diffracting crystals are in progress. Experiments related to fundamental temporal and spatial coherence questions and Wheeler's delayed-choice questions have just begun. The next 5 years will probably be as exciting as the past 5 years.

CHEMISTRY

Crystallographic Research

The years from 1977 through 1983 were active ones for structural studies using neutron diffraction, not only because of extensive work with single crystals but also because these years included vigorous growth in the application of high-resolution powder diffraction to structure refinement by means of the technique in which the entire diffraction pattern is fitted to a detailed crystallographic model. This technique, which has become known as the Rietveld method, has revolutionized structure studies on both sides of the Atlantic for a wide variety of materials that are not available as single crystals. Moreover, the penetrating power of the neutron makes possible the study of crystal structure under extreme conditions of temperature and pressure. Materials that have received extensive attention include compounds that contain light atoms in the presence of heavy atoms, such as organometallic compounds and heteropoly complexes; ionic conductors; superconductors; both alloys and organic compounds; framework structures, such as zeolites; simple and moderately complex compounds in which neutron and x-ray data can be combined for studies of electron density; hydrogen-bonded compounds; magnetic compounds; and simple organic and inorganic compounds in which high-precision structure analyses can be correlated with physical properties or compared with ab initio calculations of expected molecular conformations. We discuss below particular examples of some of these types of structural study.

Hydrides, Organometallic Compounds, and Heteropoly Complexes

Because of its sensitivity to hydrogen and other light atoms in proximity to heavy metals, neutron diffraction has proved invaluable in studying the structures of transition-metal hydrides and metal complexes with organic ligands exhibiting C-H/metal interactions. Between 1977 and 1983 approximately 50 metal hydride structures have been investigated by single-crystal neutron techniques, providing examples of hydrogen in terminal, bridging, and interstitial environments. Many powder-diffraction studies of binary and ternary hydrides have been carried out, including such potentially technologically important materials as $FeTiH_x$ and $LaNiH_5$. In studies of C-H/metal interactions, neutron diffraction has provided information on models for C-H bond activation processes that are of fundamental importance in catalysis. In recent years there has been increased emphasis on the study of cluster compounds, which may provide models for the bonding of hydrogen atoms and small molecules to metal surfaces. Crucial studies have also been carried out on heavy-metal-based heteropoly complexes, compounds of extensive importance as reagents and catalysts, which contain hydrogen as integral parts of the heteropoly anions.

Ionic Conductors and Ceramics

Studies of ionic conductors such as β''-alumina, AgI, Ag_2S, Cu_2S, and related ternary systems, as well as $Na_{1-x}Zr_2Si_xP_{3-x}O_{12}$ (NASICON) and $Na_3Sc_2(PO_4)_3$, are of great interest and exploit the unique advantages of neutron diffraction, in combination with x-ray diffraction, for examining details of disorder and thermal motion. Another important class of ionic conductors contains lithium in a matrix formed by a refractory metal oxide. Neutron diffraction is the key to determining the critical role of Li and accurate oxygen cage geometries in such "electronic" ceramics (e.g., $LiReO_3$, $LiTaO_4$). Such new materials have great potential, for example, in the development of more efficient small batteries.

Superconductors

Neutron diffraction has played an essential role in providing a basis from which to understand the unusual properties of organic conductors and superconductors. For example, in the partially oxidized tetracyanoplatinate complexes, the one-dimensional electronic conductivity has been studied as a function of metal-metal distance for a range of materials whose structures are known from neutron diffraction. More recent neutron-diffraction studies of organic, superconducting materials of the TMTSF family have explored the structure-property relationships that might exist between materials that exhibit superconductivity only at high pressure and materials that are superconducting on appropriate anion substitution. Neutron powder diffraction has been used to study a wide range of ternary superconducting alloys, in particular the Chevrel phase structures.

Framework Structures

Studies of zeolites are giving the first precise information on the locations of extra framework molecules and ions in these technologically important materials. For example, studies of zeolite rho with various compositions and over a wide range of temperatures have shown that this zeolite is noncentrosymmetric for most compositions. The sizes of the pores are sensitive to the degree of departure from centrosymmetry. These and other zeolite structure data are being used to test structural models of the reversible dehydration and ion-exchange properties of zeolite molecular sieves.

Charge-Density Studies

Techniques for combining high-resolution neutron and x-ray diffraction data to yield detailed information on electronic charge-density distributions in crystals have been extended from structures involving only atoms in the first row of the periodic table to compounds containing heavier elements. These studies are yielding important information on chemical bonding, including the distribution of d electrons in transition-metal systems.

New opportunities for understanding chemical bonding have been opened by the development of high-intensity polarized-beam diffractometers at the ILL, which are measuring the spatial extent of p and d electrons in complex chemical systems. Although these systems are not magnetically ordered in any sense, a strong magnetic field is used to induce a spin susceptibility. The results of such measurements, when combined with high-resolution neutron diffraction and x-ray results, can be compared with first-principle calculations of the atomic wave functions.

Hydrogen-Bonded Compounds

The study of the structures of hydrogenous solids has been one of the particular strengths of neutron diffraction ever since its early development in the 1950s, and interest in these compounds continues unabated. Particular attention has been directed toward the study of very short hydrogen bonds and the question of whether they are symmetrical. A number of cases have been found of very short hydrogen bonds that do not cross centers of symmetry, and these appear to be asymmetrical. If the crystal structure can be centrosymmetric, and if the distance between two oxygen atoms is shorter than about 2.45 Å, a symmetric O-H-O hydrogen bond is indistinguishable from an asymmetrical one with statistical disorder across the center.

High-Precision Structure Studies

The high precision currently available from neutron-diffraction structure analysis has made possible a variety of new types of studies--atomic positions may frequently be determined with a reproducibility of 0.001 Å or better. For example, investigations of a number of pyroelectric materials have shown that observed changes in polarization with temperature are consistent with the values calculated from the lattice constants and the nuclear positions. In another type of investigation, conformations of small molecules determined at temperatures about 20 K are being compared with those inferred from *ab initio* quantum-mechanical calculations. Such comparisons are providing insight into the distinction between effects intrinsic to the molecules and effects of forces in the solid.

Molecular Fluids and Molten Salts

In recent years, neutron diffraction work on "chemical" liquids has been carried out almost exclusively in Europe, where a sizable number of physicists and chemists, notably in the United Kingdom, have turned to liquid-state problems. In the United States, two small programs have concentrated on water and water-based solutions and on molten salts. It has now become clear that in order to unravel the structure of molecular fluids and molten salts, the partial structure functions descriptive of these systems must be resolved by multiple experiments with isotopically substituted samples. This requires elaborate sample preparation techniques and access to high-flux reactors or pulsed sources. The substitution method has been successfully applied to ions with isotopes having large differences in coherent-scattering lengths, such as Ni, Nd, and Cl. The method can be extended to nuclides with small differences in scattering length such as ^{12}C and ^{13}C or ^{14}N and ^{15}N. However, the large-scale investigation of these interesting systems is at the edge of the capabilities of currently available neutron sources and would greatly benefit from an order of magnitude in intensity. Structural solution chemistry has already been revolutionized by the isotopic substitution method, which allows the unique determination of ionic hydration and of ion-ion pair distribution functions. The method will be extended to the study of molecular fluids.

In order to determine molten salt structure completely, both cation and anion isotopes should be available. Salts of the type MX and MX_2 have been systematically investigated, giving special attention to the role of ion size. Future work will focus on binary melts.

Chemical Spectroscopy

With neutron molecular spectroscopy one may currently study the dynamics of molecules ranging from slow translational and rotational diffusion (10^{-6} sec) to the highest-energy internal vibrations (10^{-14} sec) at wavevectors (0.01-10 $Å^{-1}$), which directly probe molecular or macromolecular dimensions, something no other single experimental technique is capable of. However, most of this range is inaccessible with instruments at present U.S. neutron sources, as we will discuss in more detail below. Consequently, activities in this field in the United States have been somewhat limited.

Vibrational Spectroscopy

Current U.S. research efforts in neutron molecular spectroscopy are concentrated on vibrational spectroscopy in the range 25-250 meV using recently developed specialized instrumentation at reactors and pulsed neutron sources. Unlike most other spectroscopic techniques, incoherent inelastic neutron scattering (IINS) is not governed by symmetry-based electromagnetic selection rules. Instead the amplitude of the vibrational mode and the nuclear-scattering cross section of the atom involved principally determine IINS intensities. These factors favor the motions of H-atoms, and, therefore, certain kinds of normal modes (e.g., methyl torsions), which are often inactive or weak in IR or Raman scattering, have very large intensities in IINS.

Most (but not all) of the work in this field has, therefore, concerned hydrogen-containing molecules and has often played a crucial role in assignments of vibrational bands when used in conjunction with light scattering. For example, a series of experiments on compounds with very short hydrogen bonds using IINS measurements demonstrate an apparent change in the dynamics of the O-H-O bond as the O-O distance r becomes less than about 2.44 Å. This was accomplished by measuring the out-of-plane bend γ (OHO) as r decreases. It had been impossible to assign this mode in light-scattering experiments. Other cases for which IR/Raman spectroscopy is often difficult or impossible include metallic systems, some intercalated species, and inorganic complexes that fluoresce. Moreover, recent work at both U.S. and European reactors has shown that IINS provides a powerful, often unique tool for in-situ spectroscopy of chemisorbed species on catalysts over a wide range of temperature and pressure. These studies have already provided direct information on the bonding states and interactions of H atoms on the surface of Ni and Pt particles and on adsorption and decomposition of organic molecular species on these catalysts. An important advantage of IINS in such studies is that the scattering can be described by relatively simple theory, so that spectral intensities can be used quantitatively in the interpretation of spectra. For example, in the spectroscopic work on catalysts, both vibrational peaks and intensities were used to determine the geometry and force constants of surface-bound species. A series of important experiments has also been performed (in Europe) on metal cluster compounds as analog systems of chemisorbed materials. These data are extremely valuable as an aid in interpreting neutron or optical spectra of species bound on (or in) a real catalyst.

Low-Energy Spectroscopy

Low-energy neutron spectroscopy is currently done almost exclusively in Europe, where a series of specialized spectrometers has been developed over the past 5 or 10 years, primarily using cold neutrons, which have expanded the spectral range of neutron scattering by up to 5 orders of magnitude (down to 10^{-9} ev). These include superior, highly sensitive cold-neutron time-of-flight spectrometers, as well as ultra-high-resolution backreflection and spin-echo spectrometers. This capability, combined with the unique wave-vector regime available with neutrons, has opened up entirely new and exciting areas of applications of neutron scattering, not only in chemical spectroscopy but, as reflected in other sections of this report, in condensed-matter physics, polymer science, and biology.

In chemical applications, low-energy neutron spectroscopy is an extremely sensitive tool for probing the intermolecular potentials and the details of rotation and diffusion of molecular species in condensed systems. For example, neutrons can be used to measure rotational ground-state splittings (tunneling) by spin-flip scattering. These transitions are between different nuclear spin states and, therefore, forbidden in light-scattering studies. Such measurements most often require ultra-high resolution (European instruments for this purpose have achieved 0.5-µeV resolution), but some work has been attempted at U.S. reactors on triple-axis spectrometers at relatively low resolution (~50 µeV). Perhaps the most notable such example is a study of NH_3 rotations in Ni $(NH_3)_6I_2$, where both the form of the orientational potential and (by the application of hydrostatic pressure) its approximate dependence on intermolecular distance could be determined. Similar work was carried out on nitromethane and methane but could only be completed by making use of the appropriate instruments at the ILL. Thus the entire field of rotational tunneling spectroscopy, including appropriate theoretical advances, has been developed in Europe since the mid-1970s. Perhaps the most impressive example is a series of experiments and calculations on tunneling states in methane as well as its deuterated forms. In the low-temperature phase III of CD_4, e.g., eight transitions were resolved in the range 0-8 µeV on the IN-10 spectrometer at the ILL. This work has led to a detailed understanding of quantum-mechanical rotations and intermolecular potentials in the solid methanes. In an extension of this work to methane absorbed on graphite, it was possible to determine the relative importance of molecule-molecule and molecule-substrate forces by comparing tunneling levels for various types of rotations of the molecules on the surface. We should like to stress that this type of low-energy spectroscopy, when combined with IINS vibrational spectroscopy, provides a powerful and comprehensive probe for studying molecule-surface interactions.

The same general comments apply to the study of rotational and diffusive molecular motions with relatively long time constants (10^{-10} sec) by quasi-elastic neutron scattering (QNS). This is a powerful method for studying such motions in a wide variety of systems, ranging from hydrogen diffusion in metals to relaxation processes in polymers. Because of the ability to measure QNS at different momentum transfers, one can determine the details of reorientation or diffusion mechanisms on an interatomic or molecular scale. The application of these techniques and the development of advanced high-resolution neutron-scattering instruments is expanding rapidly in Europe. In fact, QNS has become a heavily utilized probe for investigation of molecular motion and diffusion in homogeneous as well as heterogeneous systems, such as zeolites, clays, clathrates, and other chemical adsorbents and intercalated materials. Measurements have been extended down to less than 1 atomic percent of molecular species.

BIOLOGY

Most of what we know about biological structures comes from the observation of radiation scattered by objects. Visible and infrared light, electrons, and x rays have provided structural information ranging from the organization of the atoms in macromolecules to the arrangement of cells in organisms. With the development of high-intensity sources and improved instruments, it has recently become possible to use neutrons as an additional form of radiation with which to study the structure and dynamics of macromolecules and molecular assemblies.

Neutrons have different scattering properties compared with the other forms of radiation that have been used and therefore can reveal different aspects of structure and, in fact, have capabilities that are uniquely useful. Isotope effects, particularly the difference between hydrogen and deuterium, can be exploited by selective labeling of the molecules of interest or of the solvent. An additional advantage is that there is no radiation damage to the specimen. Finally, neutron inelastic scattering provides the possibility of probing low-energy states of motion in biomolecular structures.

The principal biological areas in which neutrons have been applied during the past decade have been in high- and low-resolution macromolecular crystallography, in studies of molecular assemblies and molecules in solution, and in the study of some partially ordered systems. In all cases the difference between the scattering of hydrogen and the scattering of deuterium has been used as an important tool. In studies of protein crystals, for example, the location of hydrogen atoms (which are not observed in x-ray crystallographic experiments) has been studied, and their replacement by deuterium has led to ideas concerning structural dynamics. Moreover, crystallographic studies at low resolution have exploited enhanced contrast between protein and nucleic acid components of macromolecules. Specific deuteration of parts of macromolecules or macromolecular assemblies has been used to extend the range of information that can be obtained from solution scattering measurements. Similarly, studies of biological membranes and related lipid systems have provided critical information beyond that obtainable by x-ray diffraction. In the following, several examples of biological studies are discussed.

Protein Crystallography

High-resolution protein crystallography with neutrons was first attempted in Europe in the early 1960s but became truly feasible only in the mid-1970s. Currently the major facilities capable of efficient data collection exist in the United States, and a comparable facility is close to completion at ILL. Low-resolution studies of single crystals of such assemblies as nucleosomes and viruses have been attempted only at ILL and have never been performed in the United States, primarily for lack of suitable instrumentation.

Studies of protein crystals using neutron diffraction at a resolution of 2 Å or better have focused on the localization of hydrogen atom positions and on the exchange of hydrogen for deuterium. By documenting the position of hydrogens, it is possible to understand more completely the chemistry of proteins, which often involves hydrogen atoms in critical roles. Examples of such studies are myoglobin, trypsin, ribonuclease, lysozyme, and crambin. Studies of trypsin and myoglobin led to the elucidation of the location of individual hydrogen atom crucial to the activity of each of these proteins, while unexpected results concerning the details of hydrogen bonding between the enzyme and a substrate analog emerged from the analysis of ribonuclease.

A second line of crystallographic studies has been to follow the exchange of hydrogen and deuterium, using the exchange patterns to derive ideas concerning the distribution of static and dynamic regions of the structure. Examples in which important information has been gained are ribonuclease, trypsin, and myoglobin. Certain structural regions have been found to be relatively stable, at least so far as the dynamics of a molecule in a crystal are concerned. Continuation of these studies is anticipated and may shed important light on the dynamics of proteins and, possibly, other macromolecules. Of particular importance may be the comparisons with the dynamic results obtained by NMR.

A third issue that has concerned the practitioners of neutron crystallography has been the interaction of macromolecules with the solvent environment. Using neutrons, it is possible to document the occurrence of bound water molecules with much greater assurance than is the case with x rays, and ideas about solvation of proteins have emerged from such studies.

It is clear that high-resolution neutron crystallography has been an important and productive development as applied to biological macromolecules. It is expected that contributions from this approach will continue in the future and that a number of important biological issues may be addressed in the areas of protein structure, enzyme mechanisms, protein dynamics, and solvent interactions.

Low-resolution (15 Å or lower) studies in Europe utilizing contrast variation have been performed on a number of assemblies consisting of proteins and nucleic acids. Such studies are capable of delineating precise boundaries between the components and are useful if high-resolution data cannot be collected. The instrumentation is provided by modification of modern small-angle instruments, which must be equipped with large area detectors and have access to cold neutron beams (~10 Å).

Solution Scattering

This technique has been found to be of great importance in studies of biomolecules consisting of components that could be selectively masked by the use of appropriate H_2O/D_2O solvents. Instruments capable of necessary measurements are now available on a number of reactors in this country and in Europe, although the best European instruments have higher flux and are capable of lower wave-vector measurements, which permits examination of larger structures.

A number of different assemblies have been studied in solution using neutron scattering. Significant findings concerning nucleosomes, viruses, lipoproteins, ribosomes, and other systems have been derived from studies in both Europe and the United States. We will now discuss an example of such studies.

The Ribosome

More than 10 years ago, it was proposed that the organization of the proteins in a ribosome could be determined using neutron scattering from ribosomes in solution. The basic idea was to place two deuterated proteins in an otherwise hydrogenated structure. Neutron scattering from solutions of such labeled particles could then be used to obtain a measurement of the distance separating the centers of the two proteins in question. By a process of triangulation, a three-dimensional map of the positions of proteins in a complex structure can be generated. Such a map will be extremely useful in understanding functional relationships of different parts of the ribosome structure. In 1974, the first measurement was carried out. Since then, a large number of pairwise measurements have been made, and the positions of 15 of the 21 proteins of the small subunit of the *E. coli* ribosome have now been established. Once a map is obtained, the positions of other macromolecular ligands can also be investigated, as can issues concerning conformational changes that may accompany different states of activity.

Partially Ordered Systems

Partially ordered systems, particularly those involving membranes or muscles, for example, can be investigated using the same instrumentation as the solution measurements, although more specialized instruments for low-resolution crystallography have been and are being developed. Membranes, such as those of the myelin sheath, sarcoplasmic reticulum, retinal rod, and halobacterium, have been studied. Furthermore, details of lipid bilayer structure have been documented using deuterium labeling of specific sites.

An example is bacteriorhodopsin, a small protein found in crystalline patches in the plasma membrane of a microorganism. The protein is responsible for converting incident light energy into energy stored in an electrochemical gradient across the membrane of the organism, which it does by pumping protons from the cytoplasm to the outside in response to light. Understanding its structure may lead to improved ideas concerning the nature of membrane proteins and their relationship to lipid bilayers, as well as leading toward an understanding of the energy transduction process itself.

The neutron-scattering approach has been to use specific deuteration of the molecule by providing deuterated amino acids in the growth medium of the organism. In this way, individual classes of amino acids in bacteriorhodopsin can be deuterated biosynthetically. Purple membranes are then isolated from the organism, and their diffraction of neutrons is measured. Deuteration of different amino acids leads to large intensity changes, which can then be used in a model-building approach to test choices for the organization of the structure. This work is now in an advanced stage, and two of the seven helices have been assigned. Furthermore, it has emerged from this and other work that the helices are oriented so as to place polar groups toward the inside of the protein and nonpolar groups toward the outside where they may make contact with the nonpolar region of the liquid bilayer. Thus, this membrane protein is "inside-out" when compared with the normal organization of soluble proteins.

It is to be expected that further study will lead to more refined techniques of labeling and measurement and to corresponding improvements in the views of biological structures derived from partially ordered structures.

Inelastic Scattering

The application of inelastic scattering to biological studies has only just begun. After a number of efforts in Europe, a start has been made in developing both the theoretical framework and the measurement techniques that will be needed for biological studies. An example of the work carried out so far is a study of the enzyme hexokinase, which changes its conformation when it binds one of its substrates, glucose. In a series of measurements in D_2O solvent systems, French scientists have succeeded in demonstrating a change in the dynamics of the hexokinase molecule when glucose is bound. Such dynamic changes may accompany many instances of enzyme-substrate interactions and could be useful in probing the dynamic interdependence of multicomponent systems as well.

The development in the United States of suitable instrumentation for low-energy (0–10 meV) neutron spectroscopy, competitive with the best European facilities, would permit an evolution of this potentially exciting area of biological study.

Conclusion

The applications of neutrons in biology have led to important new insights concerning membrane proteins, enzymes, the ribosome, nucleosomes, the organization of lipid bilayers, virus structure, nucleic acid-protein interactions, and many other areas. It is clear that, while the techniques may appear exotic and specialized to biologists, essential and unique information is gained. There is every expectation that such gains will continue to grow in the future, as improved instrumentation and new sources are developed.

POLYMER AND COLLOID SCIENCE

The availability of SANS facilities has led to revolutionary advances in polymer science over the past decade. The substitution of deuterium for hydrogen makes it possible to extract information about the global molecular geometry of polymer molecules in the presence of high concentrations of other polymer molecules of the same chemical structure but differing isotopic composition. There are no other experimental methods for making such measurements. Results already achieved have stimulated significant theoretical advances, which, in turn, have given direction to many new experiments.

These determinations of molecular geometry are derived from the coherent, elastic component of the scattering envelope. Since polymer molecules are large, it follows that experiments at low q are of greatest significance.

Quasi-elastic scattering has played a lesser role in the study of polymers. This is partially due to the uncertainty in the theory used for interpretation and partially due to the inaccessibility of suitable instrumentation. The "best" spectrometer of this sort, the spin-echo machine at ILL does not go to sufficiently low q to be completely satisfactory. The problems that can be solved uniquely by quasi-elastic scattering are manifold, and the results are a natural extension of information obtained by other methods. Inelastic neutron-scattering measurements of the higher-energy frequency dynamics of polymers can also be quite valuable. A complete analysis requires large deuterated single-crystal samples, which are usually not available, but determination of large-amplitude modes (e.g., torsions) and density of vibrational states by incoherent scattering yields information complementary to that obtained by optical spectroscopies.

Since most of the research in the recent past on high polymers has been conducted for the purpose of the study of molecular geometry, we concentrate primarily on coherent elastic low-angle neutron scattering. The application of quasi-elastic scattering of polymers is at an earlier stage of development and will be discussed more briefly.

Areas of Special Interest

Polymer molecules are long-chain structures that are largely coiled, with molecular weights varying roughly between 10^4 and 5×10^6 and having a characteristic linear dimension, the centroidal radius of gyration (R), lying between 25 Å and 800 Å. In most cases, data obtained in a range between $0.3 \lesssim qR \lesssim 5$ are adequate, which means that for the large molecules a minimum q (momentum transfer) of 4×10^{-4} Å^{-1} is desirable, and for smaller molecules the largest q required would be 0.2 Å^{-1}. It is difficult to do experiments at low values of q at sufficiently high flux, and this has caused researchers to avoid polymer systems in which molecular weights are greater than 300,000.

In many cases, with polymeric electrolytes, for example, it is desirable to work at low polymer concentration, less than 1 percent by weight. The errors owing to low signal/noise ratios are considerable in systems of such low concentration, and the time for a single experimental run becomes unreasonably long.

The dimensions of particles in colloids are comparable with those in polymers, contrast is established by substitution of deuterium for hydrogen, and therefore the SANS requirements are of the same kind. One difference is that colloidal particles are compact, while polymer molecules are normally somewhat extended. As a result, the scattered signal from colloids is more intense, and experimental limitations tend to be less stringent. Quasi-elastic neutron scattering is used for examination of local motions such as methyl group rotation, polymer diffusion, and global dynamics of polymer molecules. The study of global dynamics is most demanding, and this aspect of polymer motion cannot be probed easily by other methods. Generally, the interest is in low-frequency motions in which long sections of the polymer molecule move in concert. The current instruments provide data at low frequency (down to 10^6 Hz) but are signal limited to q's greater than 0.02 $\mathring{A}^{-1}$, and this is not yet low enough to characterize chain dynamics fully. The limitation on q should be addressed in the development of new higher-q resolution spin-echo spectrometers.

Some Results from Neutron Scattering

The overall chain conformation of a polymer molecule in the bulk had been assumed alternatively to be (a) a random coil with no measurable excluded volume repulsive effects or (b) an ordered structure with neighboring chains strongly influencing mutual conformational arrangements. In the absence of SANS, it was not possible to distinguish between these alternatives. SANS measurements on a number of systems strongly support assumption (a), a conclusion that is now accepted universally. While the bulk state is important, it is only one line on the temperature-concentration (T-C) map of a polymer system. Most polymers are synthesized or processed under varying T-C conditions. SANS has made it possible to study the molecular behavior at these conditions. Although most measurements were made in Europe, scientists from the United States have also made major contributions in this area. Moreover, some of the modern theoretical predictions (renormalization group calculations and scaling theory, for example) have been critically compared with conventional theories (mean-field theory and perturbation theory, for example). Advancement in this area so far has mainly been due to comparison with the SANS results. Dynamical studies in this area would be greatly advanced if high-flux, small-angle spin-echo instrumentation and backreflection spectrometers became available to U.S. scientists.

The verification of the kinetic theory of rubber elasticity, a theory based on analysis of chain statistics, has been dependent on measurements of network swelling and stress-strain behavior. SANS measurements make it possible to study the deformation of the molecular chains directly. Indeed, it has already been shown from SANS that chain deformation is substantially less than predicted. While this result has been criticized as arising from improperly prepared materials, it has provoked new efforts to improve the theory. Certainly, further measurements of this kind can be expected to stimulate new interest in the molecular theory of elastomers.

Block polymer molecules contain within a single polymer chain at least two different chemical subchains. In some interesting cases, these subchains separate into two microphases owing to mutual incompatibility of different parts of many molecules. These microphases are compact, each unit containing parts of many molecules. This is a colloidal-type structure of characteristic dimension 100 Å or so. Much attention has been given to these block copolymers owing to both their theoretical interest and to their significant practical applicability. They can be and have been studied conveniently by small-angle neutron scattering in which one of the blocks is labeled by deuterium. In a few cases where this has been done, it has been possible to decide which of several theoretical analyses is preferable.

Molecular conformation in binary systems and kinetics during phase decomposition is an important area in terms of future polymeric materials. Although it is still in its infant stage, it is already clear that neutron scattering will be one of the most important tools in this area. A high-flux, low-q SANS instrument with time-resolved measurement capability will be especially valuable. This is because the kinetics of microphase decomposition will be the major factor that controls the morphology and performance of the material. Thus, it will be of great scientific and technological interest to study the molecular details of phase decomposition kinetics.

Instrumentation Needs

Small-angle neutron scattering of high polymers and of colloids has become an essential research tool. More than 100 experimental studies have been published, the majority using neutrons from the D11 SANS facility on a cold-neutron guide at the ILL. The largest concentration of polymer and colloid work in the United States has been done during the past three years at the NSF facility at Oak Ridge, but important contributions have been made by researchers at the National Bureau of Standards, the University of Missouri, and Brookhaven National Laboratory. In Europe, SANS experiments have also been performed at Jülich, Saclay, and Harwell.

Most modern instruments have two-dimensional detection, in which case scattering-intensity problems are less with isotropic materials than with oriented samples such as fibers, stretched rubber, or stretched plastics. This is a consequence of the fact that intensities for anisotropic materials are measured over a narrow azimuthal range, and much longer experiments are needed. It is significant that almost all results on anisotropic scattering have been reported from ILL, where fluxes are an order of magnitude greater than elsewhere. Similarly, studies on polyelectrolytes are most interesting at low concentration (one percent by weight or less), and reliable results from such weak scatterers require higher fluxes than are currently available.

The needs for the future are clear. Higher neutron fluxes and an ability to attain a lower range in q are needed. With existing U.S. reactors, this could be obtained by use of a cold source and a monochromator of the velocity selector type. A guide hall adjoining the reactor building would be needed for optimal resolution and flexibility. Recent work in Japan has demonstrated that useful research on some problems can be done at modest-flux pulsed sources equipped with a cold source. The possibilities for using the pulse structure of such sources in time-dependent studies will provide new opportunities when much higher-flux sources are developed.

Future needs for quasi-elastic scattering of polymers are focused on the problem of chain dynamics. The most promising spectrometer for this work is the "spin-echo" instrument, which permits a much better energy discrimination in the low-energy range than is otherwise obtainable. Thus far only a small number of experiments on polymers have been performed on the only spectrometer of this kind in use. However, the uniqueness and importance of the dynamical information that can be obtained from such measurements makes the construction of such facilities in the United States critical for research in polymer and biological systems. State-of-the-art cold-neutron time-of-flight and backreflection spectrometers would also make major contributions to future studies of polymer dynamics.

MATERIALS SCIENCE AND ENGINEERING

Neutron scattering offers a unique method of studying the response of materials to external variables such as stress, strain, temperature, and processing variables. The penetrating power of a neutron beam permits the sampling of a large volume of specimens, so that the investigation of bulk properties is possible. The energy of the neutrons is sufficiently low that the testing procedure itself does not introduce any additional damage, as may occur with electron microscopy. The sensitivity of SANS to heterogeneities in the size range from a few nanometers to about a micrometer has made it possible to follow, often in detail, microstructural changes in metals and ceramics resulting from deformation, irradiation, or processing. The appearance or dissolution of carbides, precipitates, dispersoids, voids, and microcracks, for example, can be detected, and frequently with sufficient sensitivity and precision that the kinetics of the process can be ascertained and compared with theoretical models. In many cases, the information yielded by neutron scattering on material behavior can be obtained in such detail and with such accuracy by no other method currently available.

Studies of Microstructural Changes Produced by Temperature and Deformation

It was demonstrated several years ago in Europe that SANS has the potential to monitor thermal processing of complex alloys. Little work has been done to date in this area in the United States. Recently, a SANS study has been carried out to investigate the effect of austenitizing and aging conditions on the size and density of precipitates in a precipitation-hardening high-strength low-alloy steel. The results were correlated with mechanical behavior. A study such as this can be used not only to optimize processing variables but also to determine the allowable leeway in these variables before serious degradation of mechanical properties results. SANS has been used to follow microstructural changes produced by prolonged exposure to high temperatures in a ferritic stainless steel developed for use in power-generation applications. Extended service causes microstructural alterations, which affect the mechanical properties of the steel such that it may no longer meet design requirements. Scattering experiments have given detailed information on the size and number of carbides ultimately produced at various temperatures. Deformation greatly hastens the microstructural changes associated with aging. Such changes were clearly picked up by SANS in steel samples fatigued for only a few hours. It may be concluded that service-induced microstructural changes can be detected and even analyzed in detail by SANS, even in complex alloys.

In Europe a number of investigations have been carried out in deformation-induced changes in microstructure. Advantage has been taken of the high-flux densities available in order to obtain small-angle scattering patterns over sufficiently short time intervals that the changes can be followed in situ. It should be noted that the scattering features of interest in metallurgical and ceramic studies frequently are rather large (some tens of nanometers). Their density is likely to be low. These are conditions that necessitate high-flux densities and measurement at very low values of the scattering vector. Such requirements cannot always be satisfied at U.S. facilities.

Use of SANS in the Detection and Analysis of Damage

Several recent experiments have pointed up the value of neutron scattering in the study of damage that appears in the form of cracks or voids. The ability of SANS to provide statistical information on the number, size, and shape of microcracks has been demonstrated in an elegant investigation of the ceramic $YCrO_3$, which undergoes extensive microcracking when it passes through a phase transformation at about 1100°C. It was found that the small-angle scattering cross sections from the cracked $YCrO_3$ could be fitted well by the form of the scattering expected from an ensemble of randomly oriented thin disks. By combining the SANS results with data on the elastic constants of the $YCrO_3$, it was possible to determine the number density, average size, and shape of the cracks.

Grain-boundary cavitation is a phenomenon found in many metals and ceramics subjected to deformation at elevated temperatures. It was virtually impossible to examine the details of this process until the advent of SANS made available statistical information on the kinetics of void nucleation and growth. It has been found that most of the voids produced by fully reversed cycling are surprisingly small (about 35 nm). At this size they should not be stable against surface energy forces. Void volume fractions of less than 10^{-6} can be measured and cavitation picked up by SANS after only 15 sec of fatiguing. No incubation time appears necessary for void nucleation. Since fatigue produces large numbers of small voids it is just possible to carry out SANS studies in facilities currently available in the United States (although higher-flux and lower-q limits would improve the results). However, the void nucleation rate in creep is low, whereas the growth rate is high. Therefore, successful creep cavitation studies by SANS demand the high-flux and low-q capabilities of the D-11 instrument at ILL and are not now feasible in the United States. Recent results on crept Cu from ILL measurements show that, in contrast to the case of fatigue, no voids can be detected with sizes below the predicted value of the smallest stable void. As in the case of cyclic loading, no incubation time appears to be required for void nucleation. The measured void size distributions that evolve as creep proceeds have been modeled with remarkable accuracy on the basis of one of the well-known theories of void growth. The theory generally believed to be applicable for these experimental conditions was found to give poor agreement with the SANS results. This is the first instance in which such a precise comparison between theory and measurement of grain-boundary cavitation has been possible.

Measurement of Texture and Residual Stresses by Neutron Diffraction

X-ray diffraction techniques are well developed for the measurement of both texture and residual stresses. However, the limited penetrating power of x rays has restricted the determination of these quantities to surface layers. Measurement of bulk properties has required destruction of the sample. The x-ray methodology can be applied to neutron diffraction to permit the nondestructive evaluation of texture and residual stresses as a function of depth from the surface. This use of neutron diffraction has great potential.

Several investigators have demonstrated that neutron diffraction can indeed be used to determine both texture and residual stresses throughout a component. Test pieces with known stress fields have been examined and satisfactory agreement found between measured and calculated values.

The method now has been applied to the determination of stresses in a number of situations, e.g., in depleted uranium and in composites in cemented carbides. In the latter case, evidence was found of large hydrostatic components of stress between carbide and binder, which arise because of significant differences in their coefficients of thermal expansion. The stress is relaxed by creep or fatigue. Recent measurements have shown that pulsed-neutron time-of-flight neutron diffraction also can be used to investigate residual stresses. Grain interaction stresses in a deformed polycrystalline alloy were determined and found to be in accord with model calculations. (X-ray techniques are not suitable for measuring nonuniform stresses that have a wavelength on the order of the grain size.)

Investigations of Phase Decomposition

SANS has proved to be a valuable tool in the study of precipitation phenomena, particularly spinodal decomposition. Information on the kinetics of decomposition has been obtained by following changes as aging proceeds in the maximum scattering cross section and the corresponding value of the scattering vector. Several investigators are studying spinodal decomposition in the FeCr system. A coexistence curve determined from scattering patterns was found to be consistent with a curve deduced from reversion experiments but considerably different from calculated values.

The high flux at ILL has permitted in situ observations to be made of the growth (or dissolution) of metastable precipitates. From the SANS data it was possible to determine whether zone formation at a given aging temperature took place by nucleation and growth or by spinodal decomposition. In another recently reported in situ experiment at ILL, solute partitioning occurring during unmixing of a ternary alloy was studied. Three isotopes of one of the constituents were used in order to obtain independent scattering contrasts.

6. FUTURE OPPORTUNITIES: FACILITIES AND RESEARCH

Based on the preceding scientific summaries, a number of needs and opportunities for U.S. neutron-scattering research are clear both in the short term and the long term. There is an immediate and critical need to develop state-of-the-art facilities in the United States to match and, where possible, extend the major instrumentation advances that have been made at research reactors in Western Europe in recent years and that have opened up entirely new areas of important scientific applications for neutron scattering. At the same time, it is essential to initiate without delay design studies for next-generation sources to assure long-term U.S. capabilities.

The best U.S. reactor sources provide immediate potential, not only for greatly expanded, internationally competitive facilities for cold neutron research on materials but also for new high-intensity, high-resolution thermal neutron instruments. This would involve the application and further development of cold-neutron-source and guide-tube technology to allow high-efficiency transport of neutron beams to large guide halls and provide maximum flexibility for new instrument development. It is also essential to pursue advances in supermirrors, polarization techniques, focusing monochromators and collimators, and area detector systems to optimize the sensitivity of this new instrumentation. It should be noted that research and application in virtually all of these areas, along with time-focusing and correlation techniques for time-of-flight applications, are necessary for the successful development of a new generation of instruments at both steady-state and pulsed sources. Moreover, a healthy and fully competitive U.S. program in neutron-scattering research at existing sources can be achieved by an incremental funding increase that is a fraction of the current massive difference in operating funds and capital investment between the United States and Europe. The Japanese have already mapped out an ambitious program to bridge the even greater gap in neutron-scattering capabilities that they face relative to the Western Europeans.

As pointed out in the scientific summaries, the development in the United States of new high-resolution, high-sensitivity instrumentation, and its utilization at both existing reactors and next-generation higher-flux sources, would provide major new scientific opportunities in all areas of neutron-scattering research, opportunities that are impossible to pursue by any other technique. The following provides both general and specific examples of these opportunities, which in some cases extend or summarize items discussed in Chapter 5.

CONDENSED-MATTER PHYSICS

The increased introduction of multidetector systems will greatly facilitate the search for diffuse scattering and weak satellite reflections in novel systems (e.g., charge- and spin-density waves). Moderate-resolution time-of-flight instruments of sufficiently high sensitivity at cold-source guides will permit studies of dynamics of physisorbed and intercalated atoms and molecules. Although it is anticipated that much of the spectroscopy at energies of 100 meV or higher will be performed on pulsed sources, the study of strongly dispersive high-energy excitations (e.g., high-energy spin waves, Stoner excitations) may often be done best at a steady-state source equipped with a hot source.

The development of high-resolution spin-echo and backscattering spectrometers will open new regimes in the study of slow phenomena, such as relaxation effects in glasses and viscous fluids, spin glasses, and random magnets. Diffusion of hydrogen in metals, charge transport in ionic conductors, two-dimensional diffusion of intercalates in layered lattices, and rotational tunneling in molecular crystals are further examples of studies that will greatly profit from such instrumentation. With further technical advances in momentum focusing, these instruments would also be capable of high-resolution phonon linewidth studies, which would revolutionize our capabilities in addressing anharmonic effects, particularly with regard to electron-phonon interactions in superconductors.

The use of spin-polarized neutron beams for scattering experiments has always been limited by low neutron fluxes. This is often because exotic materials unfortunately are usually available in very limited sample size in the vital initial phases of their characterization. An elegant class of experiments requiring analysis of the polarization of the scattered neutron beam has always been severely limited by low flux. The development of higher-flux sources and more efficient and versatile polarizers would permit this technique more nearly to approach its true potential. Among the important experiments in this area are studies of spin fluctuations in paramagnets, separation of transverse and longitudinal excitations in itinerant magnets, and the characterization of the nature of the ordering and excitations of materials undergoing cooperative nuclear spin orientation at low temperatures.

CHEMISTRY

Most of what has been accomplished to date in neutron spectroscopy of molecules in condensed systems has only scratched the surface of what it is possible to do with neutrons in this area--this will clearly be one of the major growth areas of neutron-scattering research in the future. The development in the United States of high-resolution, low-energy spectroscopy instrumentation, which provides perhaps the most unique information with respect to other methods, is a particularly critical need. It would open up for the first time in this country detailed studies of tunneling phenomena, rotational processes, and diffusion in molecular solids and in molecules bound in homogenous and heterogeneous chemical media. At the same time, the U.S. pulsed-source effort combined with existing reactor instrumentation can provide the higher-energy vibrational spectroscopic capability that is needed. The special sensitivity of neutrons (e.g., to H atom motions in optically opaque media) and the ability to interpret spectroscopic intensities directly provide unique opportunities in a number of areas. A more unified approach in the use of quasi-elastic, low-energy rotational and vibrational spectroscopy will be needed to achieve a full understanding of molecular dynamics, interactions, and bonding in a number of systems (e.g., chemical adsorbents and catalysts, intercalated materials). It should be noted that much of future activity in neutron chemical spectroscopy will involve the use of difference spectra and isotopic substitution, where the signal from the species of interest is small compared with that from the surrounding media. This, combined with the fact that often the sample sizes available for spectroscopic studies of new novel compounds are very small, will require development of much more sensitive instrumentation and higher-intensity sources than are currently available.

In the area of chemical crystallography there is a great opportunity by a combination of increased flux (from more intense sources) and the use of area detectors, which would provide up to a factor of 100 improvement in sensitivity, to expand the range of applications of neutron diffraction to new classes of materials, e.g., inorganic complexes and ceramics, which are only capable of growth as very small (<1 mm^3) single crystals. As another example, such increases in data rates would also open up new applications of neutron diffraction for real time (~1 sec) in situ studies of solid-state chemical changes occurring during the processing of bulk ceramics, including new kinds of "electronic" refractory materials.

BIOLOGY

Future opportunities for biological research fall in the areas of crystallography, solution studies, and molecular dynamics.

Neutron crystallography at high resolution has been well developed in studies of small proteins but would greatly benefit from higher-flux sources to allow extension to larger proteins, which must be explored to probe fully the structure of biological systems. Low-resolution crystallography clearly requires improved instruments and higher-flux sources of subthermal neutrons. There are no low-resolution, cold-source-based diffractometers in the United States that are comparable with the instruments available in Europe, and almost all of the major contributions in this area (nucleosomes, purple membranes, and virus structure) have emerged from recent studies at the Institut Laue-Langevin. In this regard, the possibility of combining low-resolution crystallographic and solution scattering measurements using a single instrument should be explored.

Solution studies have been and will continue to be important, owing to the unique structural information provided by the hydrogen-deuterium contrast. However, there is a critical need of improved instruments for operation at long (2-15 Å) wavelengths and higher fluxes. It is significant to note that, at wavelengths in the 5 Å region, the D11 instrument in Grenoble provides an intensity more than an order of magnitude higher than any U.S. instrument. Such gains in flux or resolution or both would open up in the United States applications to a wide range of biological problems, which cannot now be approached.

Finally, it should again be stressed that the exciting potential of neutron inelastic scattering in the study of low-energy relaxation and chain dynamics in biological assemblies can only be fulfilled if modern high-sensitivity cold-neutron time-of-flight and spin-echo instruments are developed in the United States.

POLYMERS

As summarized in Chapter 5, many fundamental questions that are also of technical importance in the polymer field could be answered if low-wave-vector (q) and very-high-resolution elastic and inelastic neutron-scattering instruments using high-intensity cold-neutron beams are made available in the United States. For example, in the area of polymer dynamics, quasi-elastic neutron-scattering instruments covering an extended q range ($0.01\ \text{Å}^{-1} \lesssim q \lesssim 2\ \text{Å}^{-1}$) could provide an integrated understanding of the high-frequency motions that determine the chemical and electrical properties of polymers and the low-frequency (long-wavelength) motions that dominate the mechanical and transport properties. Neutrons can have a unique and critical role here by allowing a definitive test of various theories of polymer dynamics and relaxation phenomena.

The development of advanced high-resolution and high-intensity SANS instruments will also allow time-resolved measurements of changes in the molecular conformation and microstructure in polymer systems. An example would be studies of polymer chains under external stress either by steady-state or oscillatory shear or extension of the sample, with SANS observations made along the stress direction or phase locked with the oscillatory motion. Other important time-resolved measurements would also be opened up by state-of-the-art SANS instrumentation and higher-intensity sources, including studies of polymer phase decomposition or chemical reactions. There is also a great need for higher cold-neutron intensities to allow, for example, highly sensitive difference measurements by SANS to probe polymer-surfactant interactions related to tertiary oil recovery and other industrial applications. More-sensitive instruments would also be essential for the study of interfacial behavior of polymer membranes that have potential for future materials separation and electronic applications.

MATERIALS SCIENCE

There are major opportunities in materials-science applications if higher fluxes, along with diffractometers and SANS instruments using enhanced area detection and focusing collimation systems become available. The resulting 1 to 2 orders-of-magnitude increased sensitivity and resolution will greatly extend the size range and level of microstructural features that can be studied in bulk materials. Important advances can be made in the study of nucleation phenomena if the volume fraction of scatterers that can be detected is substantially lowered. Major improvements in neutron facilities will also permit the kinetics of processes such as precipitation, phase decomposition, coarsening, and damage accumulation to be followed in real time (~0.1 to 100 sec). Moreover, complex stress states in metals and composites can be measured with greater resolution. If much larger intensities of very-long-wavelength neutrons become available, the recent extension of SANS diffraction theory to include refraction effects could open up small-angle scattering studies of many materials phenomena that are too large to be described adequately by diffraction alone. These advanced capabilities for microstructure research and evaluation will provide important fundamental information directly related to the processing, behavior, and reliability of advanced structural materials.

NEUTRON OPTICS

There is considerable motivation to develop much larger perfect crystal interferometers having dimensions of a meter or more, with independently oriented and positioned beam splitters. With these devices one could seriously pursue a neutron Cavendish experiment, higher-order gravitationally induced phase shifts, and a neutron version of the Michelson-Morley experiment. Research involving long-wavelength and ultra-cold neutrons, such as an improved electron dipole moment (EDM) search, will require the development of cold sources with large beams and high fluxes.

Role of Pulsed Sources

While many of the opportunities outlined above can also be addressed in a complementary way by spallation neutron sources (most particularly in neutron-diffraction applications), these sources are new, and we are just beginning to learn how to use both their spectral and pulsed characteristics. The current favorable position of U.S. pulsed-neutron research provides an ideal opportunity to develop these characteristics over the next few years. We already know that pulsed sources are superbly matched to research in both high-resolution and low-resolution diffraction from powders, glasses, and liquids. They exceed reactor sources for applications requiring high-Q or extreme (e.g., high-pressure) environments. In addition, it is clear that time-of-flight spectroscopy above the thermal neutron range will rapidly become the province of these sources, as improved instruments and higher peak intensities are achieved. However, competitive application of pulsed sources to subthermal neutron-scattering research and to studies of the dynamics of ordered or single-crystal specimens will require the development of new-generation sources and instrumentation. The effective use of cold and "cool" moderators in pulsed sources is an important area, which must be explored further.

For the present, the biggest challenge for spallation sources is how to exploit their rich epithermal spectrum. For example, recent measurements of spin waves up to 150 meV from iron using single crystals, and of electronic crystal-field transitions up to 250 meV in oxide systems, indicate the opportunities in certain applications (magnetic systems, metal hydrides) for the study of high-energy excitations. Similarly, recent incoherent-neutron-scattering studies of high-energy modes in hydrogen-bonded systems show the potential for important neutron spectroscopic applications where optical methods cannot provide needed information on the dynamics of chemical systems. Ultimately, the use of the pulsed structure of these sources by a sequenced application of a variety of stimuli to the sample could open up new applications of neutron scattering.

In sum, pulsed sources open up an extended region, of (Q,ω) space, and within the next few years we can expect new aspects of condensed matter to be found that lie in this regime. This has been the lesson of neutron scattering for the last 30 years, and we see no reason to change this optimistic view.

Concluding Remarks

One of the clear conclusions that emerges from the recent rapid advances in neutron-scattering instrumentation and sources abroad, and from the more modest developments in the United States over the past few years, is that there is a much broader community, covering many disciplines, that needs and will respond to new and modernized capabilities in neutron-scattering research. Thus, it seems clear that the provision of a new generation of neutron instruments outlined above would more than double the existing neutron-scattering user community, particularly if instrument development is combined with incremental personnel resources to allow a more effective effort for the assistance of users. The role of workshops for the user community and effective user policies and procedures for neutron facilities will also be essential. In fact, it is our view that the increasing importance of neutron-scattering facilities to a broad range of disciplines and users requires the active participation of representatives from these diverse fields in the planning of new instrumentation and sources. Moreover, in order to assure that future neutron sources meet the total needs of U.S. science and technology, it is essential that the university, industrial, defense, and federal laboratory communities have a direct role in establishing the appropriate balance of capabilities to be included in such new sources. It seems most appropriate that an independent, broadly based advisory group should be established by the National Academy of Sciences to provide guidance to the government on the technical characteristics, user policies, and siting of future major neutron centers.

Our examination of existing U.S. neutron sources suggests that a program to allow the United States to achieve an internationally competitive position with other industrialized nations in neutron-scattering research would require an increase from all funding sources of an average of ~$15 million/year (in fiscal year 1983 dollars) capital expenditure over a 5-year period. This would allow, e.g., the timely development or modernization of ~30 critical instruments, including associated cold-source and experimental-hall construction, to meet the new multidisciplinary science opportunities outlined above. A gradual rise in personnel and experimental support to a total increase of ~$12 million at the end of this development phase would be required to allow the science to be done and provide incremental resources for the assistance of hundreds of additional users. Such an investment can be compared with the ~$300 million capital investment in Western Europe during the past decade and the current >$50 million difference in scientific operating expenses between the United States and Europe.

Finally, we would address both the need and the opportunity to plan for a new generation of neutron sources for the mid-1990s and beyond. While current U.S. steady-state sources are and will remain competitive for at least the next decade in innate intensity (if not flexibility), these sources will be between 20 and 25 years old in 1990. We must consider ways in which their capabilities can be replaced with even greater capabilities to meet future scientific needs. Currently, new designs are under consideration for an advanced research reactor featuring increases in power density and total power, which would produce a steady-state flux of about 5×10^{15} neutrons/cm^2-sec. With improved beam-tube design in such a new reactor, it would be possible to increase neutrons at the sample position for many experiments by an order of magnitude over present generation reactors. Moreover, one advantage of a vigorous testing of pulsed sources and related instrumentation is that new accelerator advances may allow the achievement within the next 15 years of pulsed sources with peak thermal fluxes of $\sim 10^{17}$ neutrons/cm^2-sec and average fluxes above 10^{14} neutrons/cm^2-sec. For example, design studies have recently been initiated for a next-generation pulsed source based on a fixed-field alternating-gradient (FFAG) proton accelerator. If successful, such a source could ultimately achieve these flux characteristics at a lower capital and operating cost than that projected using current accelerator designs. Thus, there is an immediate opportunity to carry out systematic planning and design for new sources that will clearly be needed by the mid-1990s. Considering the long lead time for the construction and instrumentation of these sources, it is essential that support be provided so that such design efforts may be implemented quickly.

APPENDIX A. INSTITUTIONAL SPONSORS OF USERS OF MAJOR NEUTRON-SCATTERING FACILITIES IN THE UNITED STATES (JULY 1982-JUNE 1983)

UNIVERSITIES

Alfred University
Arizona State University
Boston University
Brandeis University
California Institute of Technology
Carnegie-Mellon University
Case Western Reserve University
City University of New York
Clemson University
Columbia University
Duke University
Florida A&M University
Harvard University
Howard University
Iowa State University
Lehigh University
Massachusetts Institute of Technology
Memphis State University
Northeastern University
Northern Illinois University
Northwestern University
Ohio State University
Pennsylvania State University
Polytechnic Institute of New York
Purdue University
Rice University
State University of New York at Stony Brook
Texas A&M University
University of Alabama
University of Arkansas
University of California, Berkeley
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
University of Chicago
University of Connecticut
University of Delaware
University of Georgia
University of Illinois
University of Kentucky
University of Maryland
University of Massachusetts
University of Michigan
University of Minnesota
University of Missouri
University of New Hampshire
University of Pennsylvania
University of Pittsburgh
University of Rhode Island
University of Southern Maine
University of Tennessee
University of Texas
University of Utah
University of Vermont
University of Wisconsin
Virginia Polytechnic Institute
Wake Forest University
Yale University

INDUSTRIES

Allied Corporations
American Dental Association
AT T Bell Laboratories
Eastman Kodak Company
E.I. du Pont de Nemours and Company
Exxon Corporation
Firestone Corporation
Ford Motor Company
General Electric Company
General Motors Corporation
Hercules Corporation
IBM Corporation
McDonnell Douglas Corporation
Monsanto Corporation
Phillips Petroleum Company
Raychem Corporation
Schlumberger-Doll Corporation
Southwest Research Institute
Standard Oil of Ohio
Union Carbide Corporation
Xerox Corporation

GOVERNMENT

Ames Laboratory
Argonne National Laboratory
Army Armanent Research and Development Command
Brookhaven National Laboratory
Lawrence Berkeley Laboratory
Los Alamos National Laboratory
National Bureau of Standards
National Institutes of Health
Naval Research Laboratory
Naval Surface Weapons Center
Oak Ridge National Laboratory
Sandia National Laboratory
U.S. Geological Survey

FOREIGN

Atomic Energy Agency of Denmark
Atomic Energy Agency of Australia
Chalmers Institute of Technology (Sweden)
CNRS, France
CSIRO, Australia
ETH, Switzerland
Imperial College, London
Institut Laue-Langevin
Instituto di Fisica "G. Marconi"
IVIC, Venezuela
Japan Atomic Energy Research Institute
Kernforschungsanlage Institute, West Germany
KFK, West Germany
Keio University, Japan
Kyoto University, Japan
McMaster University, Canada
Medical Biological Institute of Cambridge, United Kingdom
Monash University, Australia
New South Wales Institute of Technology, Australia
Nuclear Research Institute, Poland
Rutherford Appleton Laboratory, United Kingdom
Schumber Cambridge Research, United Kingdom
Sidney University, Australia
Technical University of Vienna, Austria

FOREIGN (CONTINUED)

Technion, Israel
Tohoku University, Japan
University of Bristol, United Kingdom
University of Edinburgh, United Kingdom
University of Grenoble, France
University of Milan, Italy
University of New South Wales, Australia
University of Oxford, United Kingdom
University of Osaka, Japan
University of Oslo, Norway
University of Strasbourg, France
University of Tokyo, Japan
University of Uppsala, Sweden
Weizmann Institute, Israel

Neutrons in science and technology

The neutral nucleon sees much use in research, ranging from particle physics to condensed-matter physics, and has applications in such diverse areas as mining, food preservation and art history.

D. Allan Bromley

In the four decades since the first controlled nuclear chain reaction made them available in abundance, neutrons have had a revolutionary impact on much of science and technology. Best known, perhaps, are the neutron's roles in energy production and nuclear medicine. However, this particle has made, and is making, enormous contributions in dozens of other areas of science and technology.

In this article we will look at a few of these other areas, emphasizing some of the neutron's more unusual applications. We will see, for example, how solid-state physicists are doping silicon by transmutation, how geologists are making chemical-element maps of the entire country, and how archeologists are using neutron-activation analysis to trace the origins of artifacts.

Much of the discussion will relate to the direct use of the neutrons themselves. No less important, however, are the radioisotopes produced through the exposure of elements to neutron fluxes in reactors. Thus far, nuclear scientists have studied about 1300 radioisotopes and 300 stable ones. But a vastly larger number are stable against immediate decay, and we know, for example, that when a uranium target is bombarded by high-energy uranium ions, such as those produced by the Berkeley Bevalac, over 6000 nuclear species are produced. The question arises—Who needs them? At long last we are entering the age of tailored radioisotopes. If clinicians or technologists now tell us that they want a particular chemical or biochemical behavior, a particular kind and energy of radiation, and a particular range of life-times, we have high probability of being able to provide all of them. As yet, we have only glimpsed the consequences of this new capability. Already, though, the isotope division of Oak Ridge National Laboratory alone reports annual sales of about four million dollars in stable isotopes and an equal amount in radioisotopes. Later, we will look at the use of gamma radiation from one of those radioisotopes—cobalt-60—in the preservation of food through bulk sterilization.

The earliest neutron sources were those comprising an alpha emitter in intimate contact with beryllium. Modern versions of these sources using plutonium-238, which has an 89-year halflife, or americium-241, which has a 458-year halflife, yield typical neutron fluxes of 5×10^{10} neutrons/second or about 5×10^{17} neutrons/year. Van de Graaff generators used in neutron production typically yield fewer than 10^{16} neutrons/year, and so give no major improvement in available fluxes. Electron linear accelerators yield about 10^{21} neutrons/year, and, like the Van de Graaff generators, give a measure of control over the neutron spectrum. Fission reactors, however, marked a major step forward, with a high-flux unit typically providing experimental fluxes of 10^{15} neutrons/cm^2 sec, or 10^{22} neutrons/cm^2 year. It is this enormous increase in flux that has made the neutron such an effective probe throughout science and technology.

It bears noting, too, that in terms of maximum attainable neutron fluxes, current nuclear-weapon designs yield up to 10^{29} neutrons/kiloton, and do so in about one microsecond. An elaborate technology has been developed to utilize this giant pulse of neutrons to determine neutron interaction cross sections via time-of-flight techniques.

Condensed-matter physics

It is in the case of condensed-matter physics that the neutron probe is uniquely powerful. There are several reasons for this. Because neutrons do not ionize the matter with which they interact, they accurately sample the bulk properties of that matter; through inelastic scattering or reactions induced at high energies, neutrons can introduce lattice distortions or impurities uniformly throughout the irradiated volume. Because of their intrinsic magnetic dipole moments, neutrons can probe bulk magnetization and spin phenomena. Finally, and most importantly, because thermal neutrons have momenta and energies that are well matched to the characteristic vibrational phonon energies of material lattices, they have unmatched power in probing the characteristics of these acoustic modes and thus the underlying interatomic forces of the solid.

In essence, in scattering studies the incident neutron beam illuminates the sample and is reflected by atomic planes. Obviously, vibrations of the atoms in these planes shift and distort the reflections. These vibrations are the so-called phonon modes. In general, however, there are other modes. In magnetic materials, for example, the individual atoms have intrinsic magnetic moments whose orientations are directly coupled to the intrinsic spins of these atoms. Because the neutron has a magnetic moment, it interacts with these atomic moments, and again from the characteristics of the reflections it is possible to deduce the magnetic structure of the lattice.

Physicists appreciated these features of thermal neutrons very soon after the construction of the first reactors. The first neutron spectrometer was mounted at a port on the Oak Ridge graphite reactor in the mid 1940s. Most of the research using neutrons to probe crystal lattices has used the so-called triple-axis spectrometer pioneered by Bertram N. Brockhouse at Chalk River.

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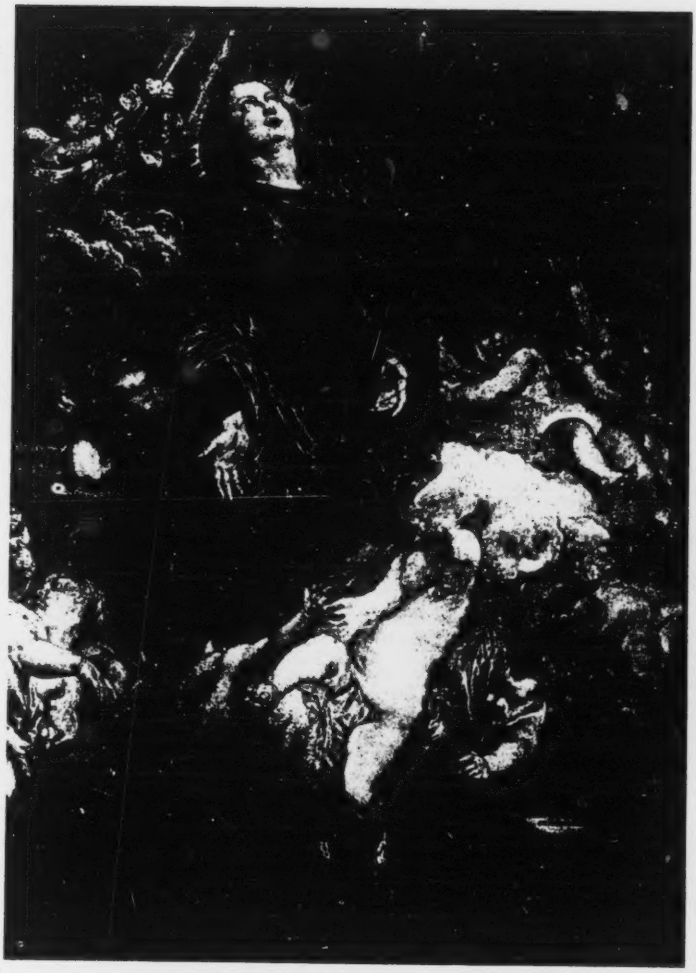
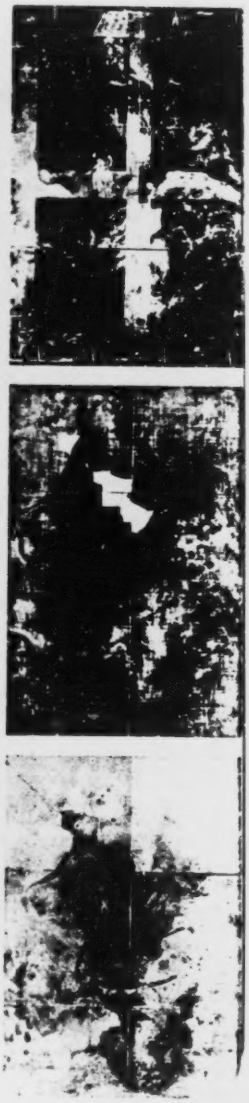
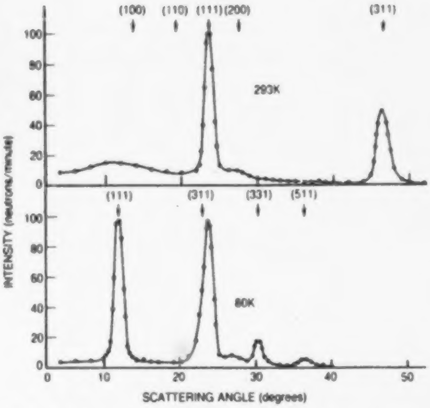




Saint Rosalie Interceding for the Plague-stricken of Palermo, by Anthony Van Dyck (1599–1641). Above is an ordinary photograph of the painting. At the upper right is an x-ray image, which, while difficult to interpret, reveals a hidden underpainting of the face of a man upside down near the bottom of the picture. The middle image on the right is an autoradiograph taken a few hours after the painting was activated with neutrons. The image at the lower right is another neutron-activation autoradiograph, this time started four days after activation. The remarkable detail here shows the underpainting to be a self-portrait of Van Dyck himself. (Images from Brookhaven National Laboratory.)



Neutron-diffraction results, from an experiment on manganese oxide. The pattern seen below the Néel temperature of 122 K shows additional reflections due to scattering form an antiferromagnetic lattice. (Figure from Oak Ridge National Laboratory.)

Neutrons from the reactor core are filtered and collimated and then monochromatized by Bragg scattering from a crystal on the first axis. These monochromatic neutrons are then scattered from the specimen on the second axis and analyzed on the third axis by yet another crystal scatterer before being detected. In this way, both energy loss to and energy gain from the specimen are readily measured, as are dispersion and, through choice of appropriate crystals or magnetic mirrors, polarization phenomena.

The box on page 35 contains a comprehensive listing of the many areas of condensed-matter physics to which neutron-scattering studies have already made very important contributions. Obviously, in a single article I cannot hope to provide complete coverage of so rich a scientific spectrum. What I have chosen instead is a very personal selection of studies to illustrate the range of physics accessible to the neutron probes.

Phonon and magnon interactions. In 1955, Brockhouse and Alec T. Stewart were the first to observe direct interaction of thermal neutrons with lattice phonons. In their experiment, neutrons traveling through a single crystal of aluminum both lost *and* gained energy through scattering, thus providing new information on the interatomic forces in the crystal lattice and the normal modes of vibration. Typical phonon modes in crystals have frequencies in the range of 10^{11} to 10^{13} Hz and wavelengths of about one angstrom, comparable to normal lattice spacings.

If one of the atomic moments is disturbed, its coupling with its lattice neighbors initiates a characteristic disturbance—the so-called spin wave, in which the precession angle changes by 2π radians, that is, by one full wavelength, after a number of interatomic distances. The energy required to establish such a spin wave—also called a magnon mode—obviously comes from the incident neutron. An established spin wave can give up energy to an incident neutron beam. This interaction depends on the magnitude of the atomic magnetic moment and on the orientations of the neutron spin and the atomic magnetic moment with respect to the scattering vector and with respect to each other.

Consequently, one can obtain detailed information on both the magnitude and orientation of magnetic moments in any substance that displays magnetic properties. Each type of magnetic lattice has a characteristic neutron scattering pattern. For paramagnetic materials, where the atomic moments are uncoupled and randomly oriented, the magnetic scattering is diffuse. For ordered magnetic lattices, the magnetic scattering is found in Bragg reflections.

Antiferromagnetic lattices are those in which the magnetic moments of the atoms become ordered spontaneously below a critical temperature, called the Néel temperature, but the ordered arrangement produces no net moment within the magnetic unit cell. The existence of this type of magnetic state was suggested by the French physicist Louis Néel in the early 1930s on the basis of macroscopic magnetic properties, and it was confirmed at Oak Ridge in 1949 by neutron-diffraction experiments on manganese oxide powder. This investigation is one of the classics in the field, and the diffraction patterns obtained at that time are shown in the figure above. These are patterns taken above and below the Néel temperature of 122 K. The room-temperature pattern contains only nuclear reflections corresponding to the atomic positions. In the pattern at 80 K, the additional reflections occurring at different angles are characteristic of scattering from an antiferromagnetic lattice. Not only did this investigation confirm the existence of antiferromagnetism, but it also gave the first experimental confirmation of the theory of indirect magnetic interactions, called superexchange. The antiferromagnetic coupling takes place indirectly through oxygen anions that are located between neighboring manganese atoms with antiparallel moments.

Magnetic phase transitions are of particular interest in modern physics. They present a special case of the general problem of phase transitions on which we have seen major progress in recent years, as witnessed by the award of the 1982 Nobel Prize in Physics to Kenneth Wilson of Cornell. To oversimplify, the goal of theoretical work in this field is that of reproducing experimental observations in the regions of the transition temperatures T_c as functions of temperature T in the form $(T - T_c)^{\beta}$, where β is the so-called critical exponent. What has been found is that this exponent depends almost not at all on the nature of the physical system under consideration and almost entirely on two simple parameters—the order of the phase transition and the dimensionality of the problem. This simplicity represents a triumph of theoretical insight. The total scattering cross section for neutrons on iron, for example, shows in the region of the Curie temperature typical behavior for a second-order phase-transition—second order in that it is the first derivative of the cross section rather than the cross section itself that is discontinuous at the Curie temperature. Microscopically, as iron approaches the transition temperature T_c, fluctuations in the alignments of the atomic moments become strong, long-range and slowly varying with time, so that the neutron-scattering cross section increases.

Iron is a typical three-dimensional magnetic system. However, there is also great interest in special systems that display effects of lower dimensionality. The complex crystal tetramethyl ammonium manganese chloride, called TMMC, is an almost ideal example of a one-dimensional Heisenberg antiferromagnet, and has been studied extensively at MIT and elsewhere. There are also a great many systems in which effective two-dimensional systems appear as sheets of magnetically coupled ions. Neutron-based measurements on such systems have provided some of the most critical data underlying our new understanding of phase phenomena. (See, for example, PHYSICS TODAY, July, page 17.)

Probing superconductors. Neutron scattering has also turned out to be a very effective probe for phenomena occurring in superconductors. In general, metals in the superconducting state expel any external magnetic field that is less than some critical strength.

For the class of superconductors known as type II, however, there is a field regime in which magnetic flux penetrates the otherwise diamagnetic matrix in the form of quantized tubes that are known as fluxoids. The fluxoids arrange themselves, depending upon the nature of the host crystal and the direction of the applied field, in a two-dimensional periodic structure known as the fluxoid or flux-line lattice. The spacing in these lattices is typically 1000 Å, which makes them suitable for study by small-angle neutron scattering. The first such studies, carried out in Saclay in 1964, found triangular flux-line lattices in niobium. More recent neutron-scattering studies have focused on the compound V_3Si, one of a very important group of high-field superconductors.

Utilizing radiation damage

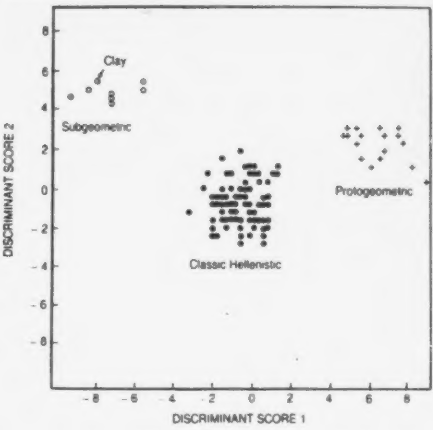
Neutrons do more than scatter when they interact with matter. It is well known, for example, that high-energy neutrons can transfer sufficient momentum to lattice nuclei to move them permanently from their normal lattice sites, creating dislocations and voids. Additionally, reactions such as (n,α) produce helium, which can collect to form bubbles that greatly reduce the mechanical integrity of the solid, result in flaking of its surface, or both. Obviously, such effects are of great importance in the construction of both fission and fusion reactors, for example, and much research has been devoted—with signal success—to the development of new alloys. These materials are designed to retain the desirable corrosion resistance, strength and other normal properties of stainless steel, while greatly reducing the development of voids and dislocations by making it easier for displaced lattice atoms to find their way back to normal lattice sites.

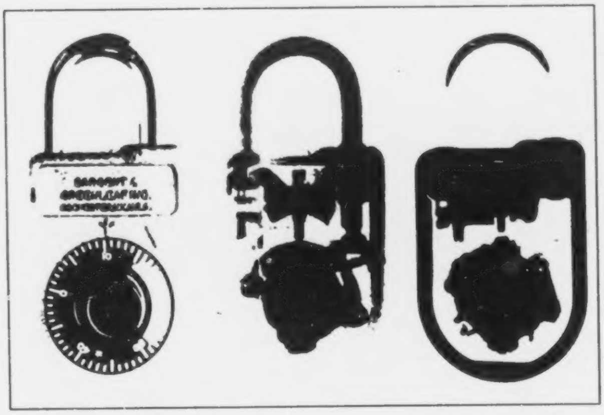
This cloud of radiation damage has a silver lining in the case of bulk neutron irradiation of silicon. Normal silicon has a 3.1% abundance of Si^{30}, which captures a neutron to form Si^{31}, which in turn decays with a halflife of 2.6 hours to form stable P^{31}. This phosphorus is *uniformly* distributed throughout the silicon to an extent totally beyond anything achievable by any other method of doping silicon with phosphorus as an electron donor impurity. Because of its uniformity of doping, this so-called neutron-transmutation-doped silicon is capable of handling high power levels when fabricated into devices such as rectifiers for use in bulk power transmission. It is also particularly well suited for the fabrication of infrared detectors, which require about 10^{12} phosphorus atoms/cm^3. Finally, because one can control the doping level with great precision by adjusting the applied neutron flux, neutron transmutation doping is increasingly being used to compensate for the inevitable traces of boron in all silicon, thereby producing what is effectively ultrapure intrinsic silicon from which the manufacture of devices can begin.

Current world production of neutron-transmutation-doped silicon is 50 metric tons per year. Annual production in the United States—at the University of Missouri and at CintiChems Inc.—is about 12 metric tons, and the demand is growing rapidly.

Finally, let me combine the last two applications and consider a very positive use of radiation damage in silicon. For a long time it has been recognized that as the density of integration of electronic devices on a single chip increases, the probability becomes appreciable that there will be errors caused, for example, by charges gener-

Compositional groups and vase. Each point in the plot represents a pottery fragment whose elemental concentrations have been calculated and added after being weighted according to two different schemes. The weighting is chosen to maximize the difference between compositional groups and allow determination of the site of production. The photograph shows an example of black-glazed Athenian pottery form the Classic period (480–320 BC). (Figure from Brookhaven National Laboratory.)





Combination lock as seen in a photograph (left), neutron radiograph (center) and x radiograph (right). To make a neutron radiograph, one places a "converter," usually a hydrogenous foil, over the photographic film, which registers protons knocked out by an incident neutron beam. Neutron imaging highlights the light elements, which preferentially scatter neutrons out of the beam. (Images courtesy of United States Department of Energy.)

ated along the ionization column of an alpha particle entering the device from contaminant uranium or thorium. These are the so-called "soft failures" of computer systems. Peter J. McNulty discusses this process in detail in his guest comment, PHYSICS TODAY, January, page 9.

At current levels of integration, the problem is particularly severe in charge-coupled devices because individual bits may be represented by no more than 50 000 electrons. According to James Ziegler of IBM and William Lanford of the State University of New York, the ultimate limitation is set by cosmic-ray neutrons creating recoil silicon ions and charged reaction products in the silicon. This source of soft failures becomes ever more important as the degree of integration is increased. Lacking any cure, the only remedy is vastly more complex—and expensive—error-correcting software. Happily, however, the same neutron that brings the problem also brings part of a solution!

Investigators using the University of Missouri reactor have found that fast-neutron irradiation of memory units in bulk can reduce their soft-error rate by a factor of 10. Apparently the radiation damage produced in the silicon substrate reduces the intrinsic resistivity sufficiently so that liberated charge along the ionization column of any incident charged particle dissipates much more readily and thus has a smaller probability of resetting a bit. Indeed, this bulk-neutron treatment frequently brings to life memory units previously discarded as nonfunctional!

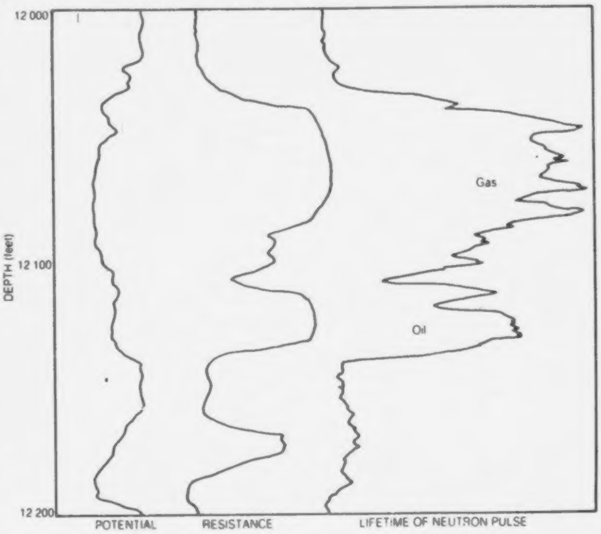
Neutron activation analysis

I turn now to the use of the neutron as an analytic probe of exquisite sensitivity. Perhaps the most familiar technique is that of neutron-activation analysis, where the sample is placed in a neutron flux; neutron capture then produces radioisotopes whose decay radiation is a unique signature for the elements originally present in the sample. There are two primary variants of this technique. In one, the irradiation and the radiation detection are separated in time by any convenient period, while in the other, the gamma radiation from the decaying radioisotopes is observed during the neutron irradiation. The latter technique is known as prompt-gamma neutron-activation analysis.

The sensitivity attainable differs from element to element, depending upon the capture cross sections and the technique used. Typical sensitivities of neutron-activation analysis, expressed as a fraction by weight of the sample, are 10^{-5} to 10^{-4} for sulfur and iron, 10^{-9} to 10^{-8} for zinc and mercury, and 10^{-12} to 10^{-11} for manganese and indium. These sensitivities are based on measurements following a one-hour exposure to a flux of 10^{13} n/cm^2 sec.

In prompt-gamma neutron-activation analysis, the sensitivity depends critically not only on the neutron capture cross section but also on the probability that the nucleus of interest emits a single strong gamma ray readily distinguishable from those characteristic of the surrounding material.

Archeology as well as paleontology draw on neutron-activation analysis. The first quantitative use of this technique to characterize archaeological materials was carried out in the chemistry department of Brookhaven National Laboratory in the mid 1950s.



Neutron scattering studies in condensed matter

Crystallography
- Crystal structures in materials containing hydrogen
- Crystal structures containing atoms close in atomic number
- Hydrogen bonding
- Hydrogen positions in a protein—myoglobin
- Ferrites
- Ferroelectrics

Magnetism
- Antiferromagnetic structures
- Ferromagnetic structures
- Superexchange mechanisms in magnetic compounds
- Magnetic properties of iron-group metals
- Magnetic properties of rare-earth metals
- Magnetic form factors
- Amorphous magnetism—spin glasses
- Production of polarized neutrons by diffraction
- Magnetic excitations
- Spin dynamics of iron and nickel

Lattice dynamics
- Phonon dispersion curves
- Interatomic forces
- Localized vibrational modes of impurities

Alloys
- Order-disorder in transition-metal alloys
- Magnetic-moment distribution in magnetic alloys

Liquids
- Structures of liquids
- Dynamics of liquids
- Rotons in helium-4
- Bose–Einstein condensate in superfluid helium-4

Superconductivity
- Flux-line lattices in Type II superconductors
- Magnetization distribution within a fluxoid
- Reentrant superconductors
- Coexistence of magnetism and superconductivity
- Electron-phonon interaction
- Phonon anomalies

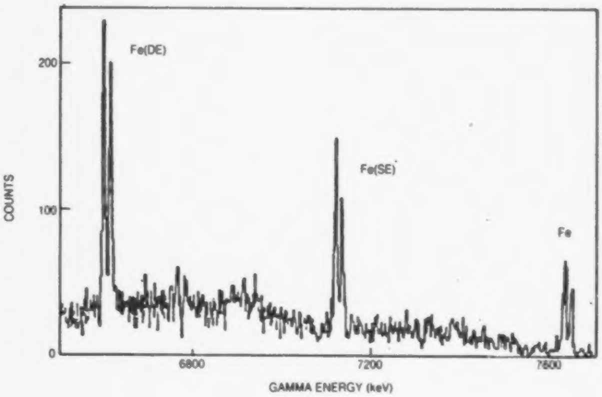
Phase transitions
- Soft modes and structural phase transitions
- Critical magnetic scattering and magnetic phase transitions
- Low-dimensional systems

Other
- Polymer conformations by small-angle neutron scattering
- Voids in irradiated materials by small-angle neutron scattering
- Voids in oil shale by small-angle neutron scattering
- Complex defects
- Electric dipole moment of the neutron
- Neutron interferometry

Based on material from Oak Ridge National Laboratory

Since then, many laboratories throughout the world have applied the technique to a great variety of materials, such as pottery, stone and minerals, glass, metals, paper and fabrics. In these studies, investigators usually measure a large number of trace components in many specimens, and then compare and group the results by multivariate statistical procedures. Specimens showing close agreement in the concentrations of many components are taken as having common origins, as the probability of obtaining such coincidence accidentally is very low.

Drillhole logs. Curves at the left show electrical potential, electrical resistance and the lifetime of a scattered neutron pulse, all as a function of the depth of a probe. Gas- and oil-bearing geologic strata reveal themselves most clearly to the neutrons. The gamma spectrum below indicates iron-bearing rock. Iron emits a characteristic gamma ray when it captures a neutron. (Figure from L. Rybach and A. H. Youmans; see bibliography.)



The usefulness of such trace-element characterization is illustrated by the recent analysis at Brookhaven of a large group of pottery fragments excavated in the ancient Agora of Athens. These specimens contained early pottery of the Protogeometric period (1000–900 BC) and Subgeometric period (750–650 BC) as well as the Classic (480–320 BC) and Hellenistic (320–30 BC) periods. In addition, specimens from Corinth and Aegina were analyzed for comparison. The figure on page 33 shows a plot of two discriminate functions, which are linear combinations of elemental concentrations chosen to maximize the difference between compositional groups. This demonstrates that the Athenian pottery of the Classic and Hellenistic periods have a consistent compositional pattern that differs significantly from that of earlier pottery from Athens and from the pottery of other Greek regions tested. Among the matching Classic and Hellenistic specimens are a number of pottery factory workshop "wasters" excavated from such workshops in the Agora itself. Therefore, one can be certain that pottery of this composition was indeed produced in Athens. The photograph shows a fine example of such Classic black-glazed Athenian pottery.

Art history. The world of art was not long in realizing that neutron-activation analysis opens an entirely new window through which the art treasures of the past might be viewed. The technique was developed at Brookhaven and is now used at a number of centers in this country and abroad. It involves exposing oil paintings to a broadly spread, highly purified thermal neutron flux of approximately 10^9 neutrons/cm^2 sec for periods up to one hour, generating within these paintings temporary, mild radioactivities. At various times after activation, one places x-ray film on the painting to record images that show the distributions of the most predominant radioactivities. A typical measurement of a painting involves a sequence of nine autoradiographic images. These images usually show significant differences from one another, as they are generally the records of radioactivities of quite different halflives. All of them are very different from the conventional x-ray image of the painting, which is largely determined by the distribution of the dense pigment lead white, a material that neutrons do not activate strongly. The activity that is primarily responsible for the autoradiograph is beta emission from the activated painting.

An interesting example of what autoradiography can reveal is provided by a study of the painting "Saint Rosalie Interceding for the Plague-stricken of Palermo," by Anthony Van Dyck, which is in the collection of New York's Metropolitan Museum of Art. A photograph of this painting is shown at the left in the figure on page 30 and its x-ray image is at the upper right. The x-ray image reveals details of a hidden underpainting—the face of a man, upside down near the bottom of the picture. It is difficult to interpret this overpainted face in the x-ray image, as it is masked by many details of the surface painting.

A neutron-activation autoradiograph of this painting, middle-right in the figure, taken only a few hours after activation, largely records the distribution of manganese, which is probably present as a component of the dark earth pigment umber. This radiograph shows details of the canvas where it had been filled in by an umber-tinted ground-paint layer. Two regions of loss are very noticeable in the upper center, where original areas of the painting have been replaced by modern repairs, which are free of manganese. The details of the figures in the Saint Rosalie painting can be seen to have the quality of drawings, and indeed art historians who have examined this autoradiograph believe them to be the underdrawings, in umber, of the original figures of the painting. It is interesting to note that the angel above and behind Saint Rosalie's head does not appear in the original underdrawing. Evidently this angel was added later in the development of the painting, a change in its initially conceived composition.

A later autoradiograph, shown at the lower right in the figure, was started four days after activation, and shows the overpainted man's head in remarkable detail. This autoradiograph is largely from the element phosphorus in the bone black used to define the head. Comparison of this autoradiograph with a self-portrait of Van Dyck, also in the Metropolitan's collection, shows that the overpainted picture is a portrait of Van Dyck himself.

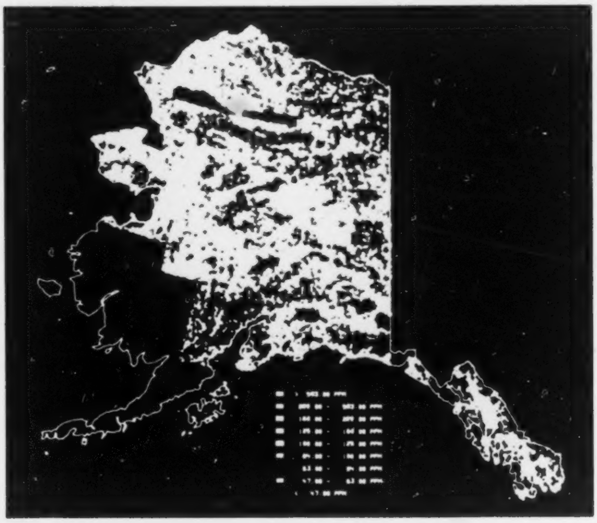
Obviously, this ability to unravel a painting gives art historians an entirely new dimension of analysis. One use they have made of autoradiography is to establish art fraud. (See Stuart Fleming's article on detecting art forgeries, PHYSICS TODAY, April 1980, page 34.) The well-known American artist Ralph Blakelock (1847–1919) was a prolific painter, but there has been a growing suspicion in art circles that some of the supposed Blakelocks are forgeries. An autoradiograph of a section of one of these paintings shows what appears to be the partially erased signature of Blakelock's daughter Marion, also a painter, strongly suggesting that someone attempted to pass off the work of the daughter as that of the father—with an eye to substantial profit.

Mining

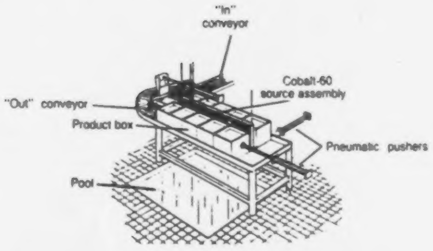
Neutrons have become of vital importance to the mining industry since geologists began using them to log geologic strata deep underground. The figure on page 35 illustrates two quite different aspects of this use.

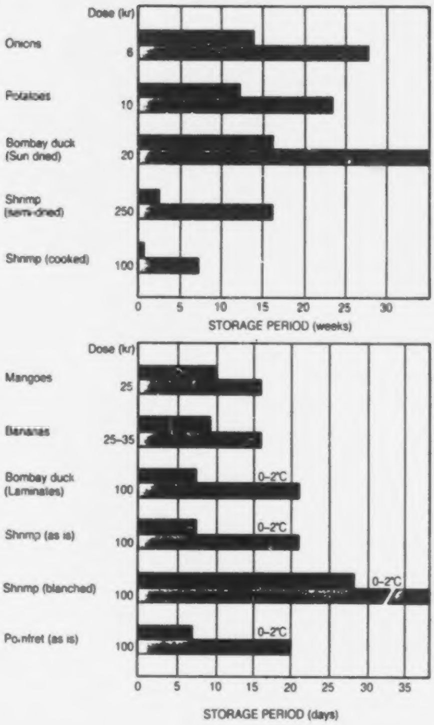
The typical exploration drill hole is some four inches in diameter; early use of neutrons in drill-hole logging used small sources based on the (α,n) reactions that take place when natural alpha-particle emitters are intimately mixed with beryllium powder. A typical drill-hole probe includes the neutron source followed by a heavy shield and a neutron counter. The counter is unable to see the source because of the shield, but is able to see neutrons scattering back from the surrounding rock. This counter is followed typically by a second shield and a gamma-radiation detector also able to view the rock but not the source.

The panel on the right in the figure shows the response of such a gamma-ray detector when the probe is in the vicinity of iron-bearing rock. We see



Chromium map of Alaska, showing the sedimentary distribution of the element over almost the entire state. Areas with chromium concentrations greater than 220 parts per million are shown in red. Yellow indicates 100–160 ppm, and blue indicates concentrations of less than 84 ppm. Data are from neutron activation analysis of samples collected on the ground. (Image from Los Alamos National Laboratory.)





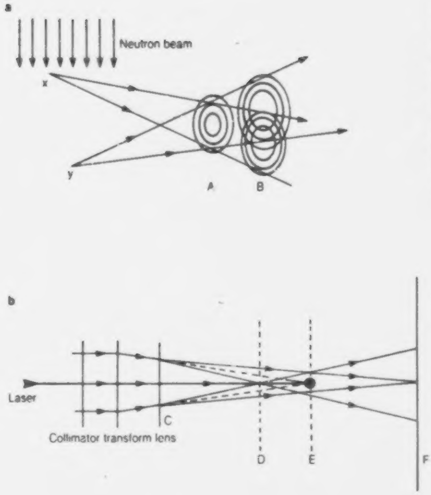
Food irradiation for preservation. The continuous irradiator diagrammed here sits above a pool of water, which insulates the cobalt-60 gamma-ray source when it is not in use. Black and colored bars in the graphs show shelf lives of normal and irradiated foods respectively. Storage is at 25° to 30° C except where otherwise indicated. Photo compares unirradiated (left) and irradiated (right) potatoes and onions after equal periods of storage. Potatoes received 5 to 15 kilorads; onions, 10 kilorads. (Diagram and graphs from Bhabha Atomic Research Center, India. Photograph courtesy of Eugen Wierbicki, USDA Eastern Regional Research Center, Philadelphia.)

iron's characteristic neutron-capture gamma rays at full energy and in the single and double escape modes, where one or two annihilation photons escape undetected from the germanium gamma spectrometer. Inasmuch as each element has a characteristic gamma ray from radiative neutron capture, this technique has very wide applicability. The spectrum shown is very unusual in having essentially no confusing background; normally the geologist is faced with disentangling the signal of interest from a much more complex spectrum.

To detect hydrogen in the surrounding material—a characteristic signature of water, oil and natural gas—one monitors the neutron detector for enhanced neutron–proton scattering. By far more sensitive, however, are techniques in which the neutron source is pulsed and the neutrons are initially of higher energy—specifically 14 MeV. To this end, several companies have developed small self-contained Van de Graaff generators capable of descending the standard drill hole and generating 14-MeV neutrons via the (d,t) reaction. What is measured then is the effective lifetime of the neutron pulse following its emission from the accelerator target. One panel of the figure shows the result of such a measurement as a probe was lowered down a hole that penetrated both gas- and oil-bearing strata. Also shown here are the potential relative to a surface reference electrode and the resistance between two contacts carried by the probe. Notice that both the resistance and the neutron pulse lifetime increase dramatically in the gas- and oil-bearing regions. The resistance also rises sharply at greater depth but the neutron lifetime does not, showing that this stratum does not contain oil or gas. Typically, the neutron source operates at a pulse rate of 1000 Hz. The neutrons are emitted between 0 and 30 microsec. Gated neutron and gamma detectors sample the yield from 400 to 600 microsec, and again from 700 to 900 microsec before the cycle repeats. The neutron well-logging business amounts to many tens of millions of dollars each year in the United States alone.

The petroleum industry is discovering entirely new uses for neutrons as it considers the potential of the nation's oil shale to meet our energy needs. To assess the accessibility of such reserves, it is important to know the size distribution and anisotropy of the petroleum-bearing voids in these shales. Workers at Oak Ridge recently applied small-angle x-ray and neutron scattering to this problem.

Small-angle scattering measures structures of matter on a global scale, in the range of about 10 to 1000 angstroms. The scattering is produced by nonuniformities in density—the electron density in the case of x rays, and the scattering-length density in the



Neutron holography. The Fresnel zone plate at *A* focuses neutrons from the objects *x* and *y* on film at *B*. After demagnification, the hologram *C* produces real images with laser light. (From T. D. Benyon and A. G. Pink, University of Birmingham, England.)

case of neutrons. Small-angle scattering from shales occurs when the radiation passes from the solid matrix material to the voids. However, because the scattering length of hydrogen for neutrons is negative, the total coherent scattering length of CH_2 or H_2O is nearly zero, and filled pores scatter in a similar manner as the empty ones. This means that neutron scattering senses all the voids. On the other hand, to a first approximation the electron density of the petroleum in the voids is the same as that of the matrix, and the x rays sense mostly the empty voids.

In each case, analysis of the scattering data leads to a radial distribution of pore sizes. By detailed comparison of the x-ray and neutron-scattering data, it is possible to obtain the size distribution of the petroleum-filled voids and thus a measure of the economic potential of the shale in question.

In 1973 the Atomic Energy Commission initiated a vastly more ambitious program directed toward the mining industry. The National Uranium Resource Evaluation program was charged with making an airborne radiometric survey of the entire United States, with doing research studies on geologic mechanisms and environments that favor the concentration of uranium, and with carrying out a nation-wide hydrogeochemical survey of surface and ground waters and water-deposited sediments. In 1975 the mandate was expanded and became the Hydrogeochemical and Stream Sediment Reconnaisance survey, and the scope was broadened from uranium to cover other strategic elements as well. Los Alamos has specific responsibility for a number of western states and for Alaska. The map on page 36, based on neutron-activation analysis of samples collected on the ground, shows typical data for Alaska, giving the sedimentary distribution of chromium in parts per million over almost the entire state. Surveyers use short-delay neutron-activation analysis on samples to collect data for Al, Ba, Ca, Cl, Dy, K, Mg, Mn, Na, Sr, Ti and Va. Long-delay neutron-activation analysis gives data on Au, Cl, Co, Cr, Cs, Eu, Fe, Ha, La, Lu, Ru, Sb, Sc, Sa, Ta, Tb, Th, Yb and Zn. This program thus gives a detailed overview of the mineral resources of the country and is an invaluable aid to coherent planning. Only neutron-activation analysis provides the speed, specificity, broad spectrum and low cost that makes so extensive a program feasible.

Intense gamma sources

Everyone is familiar with the use of fission products such as Co^{60} and Cs^{137} as sources of intense gamma radiation for clinical medicine. However, these gamma sources have other important uses. One that has not been taken advantage of to any extent in this country for other than medical purposes is bulk sterilization. In India, however, where the need is more pressing and obvious, bulk sterilization of food is being introduced on a broad scale.

Because India lacks adequate storage and refrigeration facilities, over 30% of all foodstuffs there are wasted through spoilage. Moreover, lacking adequate refrigerated transport, India has not been able to translate its major protein source—the ocean—into one that benefits more than coastal areas, again because of spoilage.

The figure on page 37, with data from USDA and the Bhabha Atomic Research Center in Trombay, India, shows a bulk irradiator based on gamma radiation from cobalt-60; it is typical of those now in use for fruits, vegetables and packaged foods. The graph shows some of the current results for the extensions in shelf and transport lifetimes of various foods. The gain from irradiation is clearly enormous, but it is best measured in terms of the millions of humans saved from starvation in India alone. This technique is widely applicable in the developing world, where spoilage is a particular problem and where the energy-intensive methods of storage and preservation characteristic of the developed world are frequently out of the question. Widespread use of radiation sterilization of foodstuffs could have a greater impact on the problem of world hunger than any other single development.

This field has lagged in the developed world through lack of perceived need and through widespread psychological aversion to eating anything "contaminated" with radiation. It merits reexamination.

Particles and waves

To end this article I would like to mention some interesting facts about ultracold neutrons and discuss briefly a new technique that makes neutron holography possible.

Whereas thermal neutrons have a mean energy of about 0.025 eV and a mean velocity of about 2200 m/sec, ultracold neutrons, by definition, have energies of about 10^{-7} eV and velocities of about 5 m/sec. One can store ultracold neutrons in containers made of ordinary materials such as metal or glass, which at such low energies are totally reflecting, or by taking advantage of the interaction between suitably chosen magnetic fields and the neutron's intrinsic magnetic moment. These two techniques have attained storage times of up to about 330 seconds and over 1000 seconds, respectively.

Dispensing these neutrons is interesting. A one-meter increase in height in the Earth's gravitational field corresponds to a change in neutron energy of 10^{-7} eV, so that a rotating crank section in a neutron guide having a radius in excess of one meter can open or close the guide completely. Magnetic control is also possible.

The wave properties of neutrons

have technological implications: Neutron holography is a very new and potentially very important development in the use of neutrons, holding the potential for three-dimensional delineation of features *inside* completely closed solids. The figure on the opposite page illustrates the technique. At the top, a neutron beam illuminates two point objects *x* and *y* in space. A Fresnel zone plate composed of alternate rings of gadolinium and aluminum sits at point *A*. Behind it, in the plane at *B*, is x-ray film. To view the hologram produced at *B*, one demagnifies it optically and illuminates it with a converging laser beam. As shown at the bottom of the figure, the demagnified hologram at *C* produces a real image of the objects in plane *F*. However, because the objects *x* and *y* were different distances from the Fresnel zone plate, their real images appear at different distances from the hologram. This neutron holographic technique is still in its infancy, but it holds high promise of interesting and perhaps unique technological applications.

We have seen in this article just a few snapshots of the enormous scientific and technological terrain to which the neutron has made, and continues to make important contributions. I can say that in these areas, uniformly, the impact has been both benificent and benevolent.

* * *

This article is based on a more extensive paper given at the University of Chicago 1 December 1982, at a symposium commemorating the fortieth anniversary of the first artificially produced, self-sustaining nuclear chain reaction. The paper will appear in full in the proceedings of the symposium, which are being edited by Robert G. Sachs of the University of Chicago.

I would like to take this opportunity to express my deep appreciation to the following persons who responded so generously to my requests for information and other input to this article: Gil Bartholomew, Henry Hurwitz, James Leiss, Walter Massey, A. M. L. Messiah, Norman Ramsey, Louis Rosen, Nicholas Samios, David Shirley, Tom Tombrello and Alex Zucker.

Thanks also go to Bob Sachs and to Hanna Gray for their invitation to participate in the fortieth-anniversary symposium and for the stimulus required to make me pull together the material contained herein.

As always, I am indebted to Mary Anne Schulz, Rita Bonito and Sandy Sicignano for their assistance in the preparation of this article.

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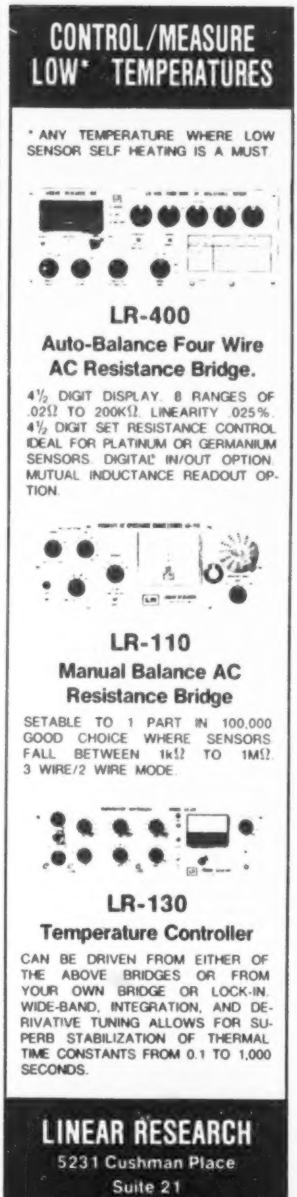

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APPENDIX 4

UNOFFICIAL TRANSCRIPTS OF THE NUCLEAR REGULATORY COMMISSION

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of:

BRIEFING ON DEVELOPMENT OF
PROPOSED RULE ON HEU AT DOMESTIC
REACTORS

Docket No.

Location: Washington, D. C. Pages: 1 - 143

Date: Monday, December 19, 1983

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

- - -

BRIEFING ON DEVELOPMENT OF PROPOSED RULE
ON HEU AT DOMESTIC REACTORS

- - -

PUBLIC MEETING

Room 1130
1717 H Street, N.W.
Washington, D.C.

Monday, December 19, 1983

The Commission met, pursuant to notice, at 2:05 p.m.

COMMISSIONERS PRESENT:

NUNZIO PALLADINO, Chairman of the Commission
VICTOR GILINSKY, Commissioner
THOMAS ROBERTS, Commissioner
JAMES ASSELSTINE, Commissioner
FREDERICK BERNTHAL, Commissioner

STAFF AND PRESENTERS SEATED AT COMMISSION TABLE:

SAM CHILK
ROBERT MINOGUE
WILLIAM J. DIRCKS
SHELDON TRUBATCH
C. N. KELBER
D. R. HARRIS
R. R. BURN
P. TURINSKY
J. KANE
R. CARTER
J. J. McGOVERN
PAUL LEVENTHAL

AUDIENCE SPEAKERS:

HAROLD DENTON
DON SMITH

DISCLAIMER

This is an unoffical transcript of a meeting of the United States Nuclear Regulatory Commission held on December 19, 1983 in the Commission's office at 1717 H Street, N. W. Washington, D. C. The meeting was open to public attendance and observati This transcript has not been reviewed, corrected, or edited,an it may contain inaccuracies.

The transcript is intended solely for general informational purposes. As provided by 10 CFR 9.103, it is not part of the formal or informal record of decision of the matters decussed. Expressions of opinion in this transcript do not necessarily reflect final determinations or beliefs. No pleading or other paper may be filed with the commission in any proceeding as th result of or addressed to any statement or argument contained herein, except as the Commission may authorize.

P R O C E E D I N G S

CHAIRMAN PALLADINO: Good afternoon, ladies and gentlemen.

The Commission is meeting this afternoon to be briefed on the status of development of a proposed rule that would require conversion of research and test reactors to low enriched uranium.

The Commission announced its interest in reducing the use of high enriched uranium (HEU) in a policy statement issued last year. Subsequent to that the Commission directed the NRC Staff to develop a proposed rule that would restrict the use of HEU in research and test reactors unless the unique purposes of the project could not be achieved without using the HEU.

The Staff, in conjunction with an organization representing affected universities set up a study group to assess the impact on the 25 university reactors currently using HEU.

Today we will discuss the results of that study, in addition to how a proposed rule would be constructed and implemented.

The Staff will be leading off the discussion this afternoon. We will also be hearing from LEU Study Group, and representatives from licensees using HEU.

In addition, we will hear from a representative of the Department of Energy, since our actions would be based upon--since actions might be based on the Congress funding DOE to provide the LEU fuel at university reactors.

We also had a request from Mr. Leventhal to appear and give a very brief statement. We will provide him about three or four minutes, no more than four, after the conclusion of a prepared agenda.

So, unless there are comments from my fellow Commissioners, I would propose to turn the meeting over to Mr. Dircks, who will introduce the Staff presentation.

MR. DIRCKS: As you pointed out, Mr. Chairman, first, we're going to have a brief summary of the history and pertinent facts; that will be given by Charlie Kelber, Deputy Director of the Division of Accident Evaluation, in the Office of Research and Standards. He has taken on as a special task this subject.

Following his brief discussion of the history and chronology and how we got here today, then we have the series of outside speakers; and we also have a brief summary of the study that was done.

Charlie, why don't you take it from here?

MR. KELBER: Thank you.

Our objective today is to set before you the information we have gathered to date, before we proceed to a specific rule development.

12/19/83

SCHEDULING NOTES

Title: Briefing on Development of Proposed Rule on HEU at Domestic Reactors

Scheduled: 2:00 p.m., Monday, December 19, 1983 (OPEN)

DURATION: 2 hrs.

Purpose: To be briefed on evaluations of the impacts of proposed rules on conversion to low enriched uranium at test and research reactors.

Speakers:
1. C.N. Kelber (RES) - 20 min. (Viewgraphs)
2. D.R. Harris (LEU Study Group) - 15 min. (Viewgraphs)
3. R.R. Burn (University of Michigan) - 10 min.
4. P. Turinsky (Nuclear Engineering Department Heads Organization) - 5 min. (Viewgraphs)
5. J. Kane (DOE) - 10 min.
6. R. Carter (NBS) - 5 min. (Viewgraphs)
7. J.J. McGovern (Union Carbide Corp.) - 5 min.

Documents: SECY-83-349

We expect to be able to develop the requested rule in a very brief period of time.

We have responded to your request for information from other groups by inviting here today representatives of the Department of Energy, the Nuclear Engineering Department Heads Organization--called NEDHO; the Ford Nuclear Reactor at the University of Michigan has furnished the conversion to LEU; and Reactor Groups at the National Bureau of Standards and Union Carbide Corporation.

COMMISSIONER GILINSKY: You know, before you go further, I think it would be helpful if you would say a word to--about why we're doing all this. I think particularly for people who are not familiar with the subject, it would be helpful.

MR. KELBER: The Commission Policy Statement-- I wonder if we could perhaps ask for the first vugraph-- which recapitulates the chronology; and the Policy Statement expressed the Commission's interest in reducing the use of HEU by research reactors; and to strongly encourage conversion to LEU by foreign operators, as a result of showing we would be even-handed in our treatment; and that we would, in fact, introduce models for the licensing of the conversion of such reactors to the use of LEU.

The objective was, as I understand it from the Policy Statement, to reduce the traffic in HEU.

12/19/83

REVISED

CONVERSION OF RESEARCH REACTORS TO LOW ENRICHED URANIUM (LEU)

- POLICY STATEMENT (AUG. 1982) EXPRESSES INTEREST IN REDUCING USE OF HEU BY RESEARCH REACTORS
- OPE REPORT ON OPTIONS FOR IMPLEMENTING POLICY (MAR. 1983)
- COMMISSION REQUESTED (JUNE 21, 1983) DEVELOPMENT OF PROPOSED RULE PROVIDING, WITH CERTAIN EXCEPTIONS, FOR:
    1. NO NEW LICENSES FOR RESEARCH REACTORS USING HEU, AND
    2. EXISTING LICENSEES, AT REFUELING, REPLACE HEU WITH LEU,
    -- INCLUDING CONSIDERATION OF ECONOMIC FACTORS
- SECY 83-349 OUTLINED SCOPE AND SCHEDULE OF STUDY NEEDED BEFORE MAJOR EFFORTS EXPENDED TO DEVELOP RULE.

Now, in developing a rule--

COMMISSIONER GILINSKY: The point being that HEU is a material--HEU is a nuclear explosive; and in sufficient quantities could be used for weapons. And that's the source of the concern.

MR. KELBER: Well, yes; that's the driving force behind the Commission's Policy Statement, that HEU is a concern because of its--compared to LEU--relatively ready-conversion to other uses.

The subsequent action after the issue of the Policy Statement was the OPE Report, and after review by the Commission the Memorandum to the Staff, dated June 21st essentially echoed the OPE recommendation for rule that provides with certain exceptions that the NRC license no new research reactors for HEU--as I say, with certain exceptions--and require existing licensees when refueling to replace spent HEU fuel with LEU fuel.

The Memorandum expressed requirements for a deliberate approach and requested that the Staff brief the Commission on the matter before extensive efforts are spent in developing the proposed rule.

We pursued the development of information pertinent to the development of the proposed rule and particularly focusing on such questions as, feasibility, schedules, and impacts.

We received full cooperation from Department of Energy, the Office of Policy Evaluation and, of course, all the concerned offices of the NRC.

We've asked several individuals to make presentations here today, and they are indicated in our second vugraph:

Dr. Donald Harris is the Chairman of the LEU Study Group and he is present here as our contractor.

The LEU Study Group, under contract to us, conducted a comprehensive survey of the university research and training reactors to gather data related to technical feasibility, functional impacts, licensing, schedule, conversion, in accordance with the rule indicated by the Commission's Memorandum for the Staff.

And Dr. Harris will summarize the facts developed by the Study Group.

The data are by and large applicable, with some obvious exceptions, to other plans of significant concern: the National Bureau of Standards reactor at the Union Carbide Corporation. They are higher-powered plants and hence have some specific problems of their own, and their representatives are here, as I will mention.

Mr. Robert Burn, Director of the University of Michigan's Ford Nuclear Reactor, and a member of the Study Group, will summarize his experience with conversion.

SCHEDULED PARTICIPANTS

- DR. DONALD HARRIS, RPI, CHAIRMAN OF STUDY GROUP ON CONVERSION OF UNIVERSITY REACTORS TO LEU, WILL SUMMARIZE FACTS DEVELOPED BY THE GROUP
- MR. ROBERT BURN, U. MICH., WILL DISCUSS EXPERIENCE WITH CONVERSION OF MICHIGAN'S FORD NUCLEAR REACTOR
- DR. PAUL TURINSKY, CHAIRMAN OF THE NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION, WILL EXPRESS NEDHO'S VIEWS
- DR. J. KANE, DEPUTY DIRECTOR, OFFICE OF ENERGY RESEARCH, WILL COMMENT ON DOE'S INTEREST
- DR. ROBERT CARTER, NBS, AND DR. J. J. MC GOVERN OF UNION CARBIDE CORPORATION WILL COMMENT ON THEIR CONCERNS

Professor Paul Turinsky is Chairman of the Nuclear Engineering Department Heads Organization, and will express the judgments of that organization regarding the proposed rule.

The Department of Energy's Office of Research is responsible for the support of university programs, and Dr. Treblpeace (phonetic), Director of that Office, has indicated several concerns in a letter to Mr. Minogue dated November 7th, 1983; and his representative, James Kane, is here today to expand on those concerns.

We've also asked Dr. Robert Carter of the National Bureau of Standards, and Dr. J. J. McGovern, of Union Carbide Corporation, to voice their concerns.

On August 19, the Staff forwarded you an information paper outlining our plans, and these are summarized in our third vugraph.

As I have mentioned, although the major effort was on the university reactors, primarily because they are the largest group, the comments and the data developed there do apply to the Union Carbide and Bureau of Standards reactors, with appropriate modifications chiefly dealing with the thermal hydraulics of the plants, because of their higher power rating.

There is a special problem connected with Union Carbide that results from the fact that they irradiate

DEVELOPMENT OF PROPOSED RULE

- AN INFORMATION PAPER TO THE COMMISSION IN AUGUST OUTLINED THE STAFF's PLAN FOR GATHERING INFORMATION ON TECHNICAL AND REGULATORY IMPACTS (SECY-83-349)
- MAJOR EFFORT ON UNIVERSITY REACTORS PRIMARILY BECAUSE THEY ARE THE LARGEST GROUP; COMMENTS APPLY TO UNION CARBIDE, BUREAU OF STANDARDS REACTORS.
- UNDER SHORT TERM CONTRACT, THE LEU STUDY GROUP REPORTED ON THE IMPLICATIONS OF CONVERSION OF UNIVERSITY REACTORS TO LEU, MEETINGS HAVE BEEN HELD WITH DOE TO ASSURE COMMON DATA BASE.

uranium to develop fission products for use in medical diagnostics. And so they have a significant amount of uranium that they use as a market material as well as for providing neutrons.

We had several meetings among all the concerned offices in DOE to assure common data base and, I believe that that went forward very well.

We developed essentially two types of information technical impacts and regulatory impacts, at these meetings.

And we have delineated several issues on--shown on our fourth vugraph:

First, there's definition of certain key terms in the Commission guidance, unique guidance, and technically feasible; we don't believe that that is a difficult task. It simply has to be done in a way that a sound rule can be written. And we have done part of that already.

CHAIRMAN PALLADINO: Could we have a copy of that slide?

MR. KELBER: I think it's simply out of order, it may be out of order; some of these slides are out of order.

I wonder if we could go back one slide, please?

The economics and the role of federal funding is a key issue, because we note that the proposed rule is predicated on DOE financial support; and incorporating that

IN STAFF WORK WE HAVE NOTED SEVERAL ISSUES:

- DEFINITION OF KEY TERMS IN COMMISSION GUIDANCE: E.G., "UNIQUE PURPOSE" AND "TECHNICALLY FEASIBLE"
- ECONOMICS AND ROLE OF FEDERAL FUNDING
- SCOPE OF RULE

--- WORK TO BE COMPLETED IN THREE MONTHS provision into the rule itself represents a problem that might be resolved by incorporating a provision of economic feasibility; but this does require some further definition.

The scope of the rule is important--

CHAIRMAN PALLADINO: Among issues, is there not a question about less than formula quantity?

MR. KELBER: This is the scope question.

CHAIRMAN PALLADINO: Oh, okay.

MR. KELBER: To the rule as written and the policy paper address--the direction is written--attempt to address the question of traffic in HEU.

There are many reactor plants that have a) less than a formula quantity of fuel; and b) have no need to refuel during the term of their license, or even proposed extensions; so that there is no traffic of fuel in or out of the plant.

And the question then is: how should the rule affect them? Or should it affect them at all?

COMMISSIONER GILINSKY: Let me ask you: when you talk about reactors with lifetime cores, what are there, I don't know--18 or so in that category or something of that order.

MR. KELBER: Something of that order, yes.

COMMISSIONER GILINSKY: Of that order.

Are you talking about material which is in the core or they have a lifetime supply of fuel, or both?

MR. KELBER: It varies from case-to-case, but typically in the lower power plants--and there are some that are very low power, on the order of milliwatts or thereabouts--the fuel is all in the core.

And in some which operate at a more substantial power, there is an HEU, irradiated HEU, on the site that is periodically moved in, and other fuel moved out in order to spike the core.

COMMISSIONER GILINSKY: I don't think you covered in your report the extent to which the fuel is in fact irradiated?

MR. KELBER: There is a table in the report that covers, that tells the amounts--total amounts, and the amounts that are irradiated to the 100^r per hour.

COMMISSIONER GILINSKY: Uh-huh, you don't have a slide on that, do you?

MR. KELBER: I don't have a slide, but one of Dr. Harris' slides may cover that. And I can find it in the report.

COMMISSIONER GILINSKY: Because it's important that we keep in mind the security issues. After all, it's security issues that drive this whole exercise. And it's not something that can be decided entirely on the basis of these technical concerns, which is what we're considering here.

MR. KELBER: Of course, all these plants that are subject to the safeguards regulations and those which-- there are several which have quantities above the formula quantity; and, of course, they--

COMMISSIONER GILINSKY: Well, of course, the principal difficulty is the 100^{r} per hour, which is a level at which we permit them to regard the material is self-protecting, is in fact a rather low level.

That is to a substantial extent the origin of my concerns: that we allowed these licensee latitude that in effect fuel facilities and others don't have because the licensees we're talking about here didn't have to have the full panoply of guards and physical security and so on that we require of fuel facilities, for example.

MR. KELBER: We did not undertake here to extend the scope of this study to the safeguards questions, although we did have a lot of discussions with NMSS on this.

So far as we're concerned in developing a rule the sole question here is the scope; and we could certainly prepare rules with different options. And I think the policy in that question is clearly your prerogative, that all we can do is we can give you a rule that will address one or the other option.

CHAIRMAN PALLADINO: But, now, does a less than formula quantity constitute a problem?

COMMISSIONER GILINSKY: I would say so, yes

CHAIRMAN PALLADINO: Why?

COMMISSIONER GILINSKY: Because someone can take two of them and then you got formula quantity.

CHAIRMAN PALLADINO: They'd have to do it almost simultaneously.

COMMISSIONER GILINSKY: That's exactly right.

CHAIRMAN PALLADINO: And I don't see that as a credible situation.

COMMISSIONER GILINSKY: It seems to me our objective ought to be to eliminate this material from the campus, anyway. I don't know about some of the larger research reactors; but to the extent we're able to do it, and the chronology is now letting us do it for most of the reactors, if not all of them; and I expect in time we'll be able to do it for the others. And if not get them all down to low enrichment, at least get them down to a lower enrichment. Even that is important, I think.

It will have solved a big problem. Could you imagine what would happen if some of this material was stolen?

You'd have a problem, a hair-raising problem, and, in fact, the security problems at all these plants would be enormous. They'd be subjected to all sorts of requirements. The whole picture would change.

I mean, we just don't need any of that--not to speak of the fact that we're urging everyong abroad to do this.

And I think one of the things that's emerged is they're telling us it's a two-way street; and it's something, if they're expected to do it, we ought to be doing it, too.

And I think that's exactly right.

CHAIRMAN PALLADINO: Well, I think that's a more complex issue than you indicate. I think for new reactors we're in pretty solid agreement.

As a matter of fact, I'd even lift some of the caveats, or at least make sure the caveat has a high threshold.

But we do have differing circumstances, and those that are using HEU, I think we ought to listen and see how those influence any of our--

COMMISSIONER GILINSKY: Oh, sure. And that's why we are here today. We want to hear the details.

But I think it's also important to keep in mind that it is the security problem that is motivating all of this.

COMMISSIONER BERNTHAL: Well, Victor, just for my information, why is the 100^r per hour considered to be an inadequate--you seem to consider it inadequate?

COMMISSIONER GILINSKY: Well, the agency considers it to be adequate. I personally consider it rather a light level of radiation.

COMMISSIONER BERNTHAL: I'm trying to construct a scenario in my mind where you could easily deal with a fuel of that intensity if you wanted to divert material and do anything with it.

COMMISSIONER GILINSKY: I don't know if we can get into details here; but I don't regard that as a sufficient level of self-protection.

CHAIRMAN PALLADINO: That was an issue we handled separately. It may be one we want to reexamine. But there are a lot of questions that go much beyond that. You'll find that there's difficulty--

COMMISSIONER GILINSKY: Okay, sure. We get into a lot of problems. It's a vexing area.

But we would eliminate all of them if we could get over to a different kind of material. We wouldn't have any of these security problems. We wouldn't have any requirements if the material has to be irradiated, it would not have to be irradiated when it's in storage; it would simplify the handling.

And what's involved is ultimately some DOE money and a little accommodation on our part in dealing with the regulatory problem.

CHAIRMAN PALLADINO: Well, why don't we go on and hear the issues, and then--well, we can debate.

MR. KELBER: The next slide indicates our findings to date:

The key finding is that it is, given this success, continued success, of DOE's RERTR program, that it is technically feasible to convert the university reactors, the capabilities of the--

CHAIRMAN PALLADINO: You say "most" universities?

MR. KELBER: Yes.

The MIT reactor and University of Missouri research reactor, with the acronym MURR, probably could not be converted successfully even with the highest density fuel that RERTR is proposing.

Some substantial reduction in the HEU traffic at those plants, however, might result from the use of advanced high burn-up fuels now under development by DOE for their test reactors.

And one might also want to consider using a medium enrichment fuel, for example, approximately 45 percent by weight, in connection with these higher density fuels; that would significantly lower the potential

REVIEW TO DATE INDICATES:

- TECHNICALLY FEASIBLE TO CONVERT MOST UNIVERSITY REACTORS, CAPABILITIES OF MITR, MURR AND TWO INDUSTRIAL PLANTS -- NBS AND UCC -- WOULD BE SIGNIFICANTLY AFFECTED,
- MANY REACTORS POSSESS LESS THAN FORMULA QUANTITIES
- ECONOMIC COSTS AND COSTS ASSOCIATED WITH PERIOD OF SHUTDOWN ARE A MAJOR CONCERN TO THE UNIVERSITIES
- THE UNIVERSITIES WOULD PREFER TO AVOID LICENSING ACTIONS WHICH INVOLVE HEARINGS
- NBS, UCC CONCERNED WITH SIGNIFICANT DEGRADATION OF CAPABILITY AS WELL AS COSTS

from these fuels.

With respect to TRIGGER reactors, a special problem arises in conversion from 70 percent enriched to 20 percent enriched. The many TRIGGERs now do use LEU fuel, but a few in the U.S. and several abroad use 70 percent enriched; and the LEU fuels now supplied for TRIGGERS apparently cannot support a significant number of highly energetic pulses.

We first encountered this problem ourselves in 1975 when considering a TRIGGER fuel for the core in the research reactor at Sandia.

We have not determined if an LEU fuel of greater capability can be manufactured or what the cost impact of such a change would be. We haven't looked into that question.

COMMISSIONER BERNTHAL: If I can just interrupt for a minute? I'm not sure whether it's best to interrupt on some of these details; but I am here to learn to a large extent, and I am not sure whether you can answer this question here.

But my question is simply how does the scale of ease of making an explicit device somehow run in a qualitative way when you go from 93 down to, let's say, 20?

Does 45 buy you a great deal, or half or--how does it work?

MR. KELBER: I hate to admit that there's an area in this whole field that I'm not an expert in. I have to say that: making bombs is not one of them!

(Laughter)

But I would say that there is a significant decrease as you drop down below the 70 percent range; there is a significant decrease in ability.

But there are many other factors which are of concern: the state of irradiation--

COMMISSIONER GILINSKY: Well, you're basically increasing the critical mass.

COMMISSIONER BERNTHAL: Sure.

But how much more difficult does it get, I guess, to make anything--

COMMISSIONER GILINSKY: Well, it's critical mass over the density squared.

COMMISSIONER BERNTHAL: Is it a linear function, essentially?

MR. KELBER: There are tables available, but I think they are based on uranium or uranium dioxide masses; and I think that is a question here: what is the chemical composition of the fuel?

I think that, certainly, if you wanted, we could get the appropriate person from either Safeguards or from DOE to come in and brief you on this in detail.

But my impression is that--I think what expertise I do have indicates that medium enrichment does buy you a significant benefit.

The other findings are--we've already addressed them, these (indicating)

One that has been brought up to us that we did not recognize at first is that when the universities shut their reactor down for a protracted period of time for conversion, or for --are forced to shut down operations during a protracted hearing, there is a loss in terms of the research that is simply not done.

That is, our students will have to pursue their scholastic career and who do not have this tool available. There are people being trained for reactor operations who do not have this training tool available.

COMMISSIONER GILINSKY: Well, at the same time the conversion is an interesting technical exercise in itself--

MR. KELBER: Yuh.

COMMISSIONER GILINSKY: --and no doubt people would get a great deal of experience in trying that out.

MR. KELBER: I think that's certainly true.

So that it's not an entire loss; but it is certainly a different type of operation than many of them have addressed.

COMMISSIONER GILINSKY: Theorist versus the experimentalist.

MR. KELBER: Yuh.

COMMISSIONER GILINSKY: Both!

(Laughter)

MR. KELBER: So this is a concern that many have raised, it's a cost that's very difficult to quantity; and I think there are many things that the NRC, itself, could do to lower that cost.

CHAIRMAN PALLADINO: Earlier we were talking about reduction in enrichment. There comes a point at which the lower enrichment means higher U238, and that means higher plutonium production.

MR. KELBER: Yes.

CHAIRMAN PALLADINO: Where is a reasonable cut-off?

COMMISSIONER GILINSKY: I think as a practical matter it doesn't arise here. You'd have to get down to really awfully low enrichment before you had any--

MR. KELBER: In the higher power plants there is--

CHAIRMAN PALLADINO: Well, you're talking about 20 percent.

MR. KELBER: I would agree with that except for the higher power operations, where you necessarily are maki some.

Generally speaking, you get sizeable plutonium production when you get enrichments down below 10 percent or so.

As you know, the power plants--

CHAIRMAN PALLADINO: That's why we're talking 20 percent.

MR. KELBER: Yuh, yuh.

COMMISSIONER GILINSKY: Well, I think we are talking 20 percent because that's the traditional dividing line between LEU and HEU in all the rules; and that ought to be good enough, and we don't need to go any further, don't even need to talk about.

CHAIRMAN PALLADINO: Well, with regard to plutonium production, though, is that--I gather that's a cut-off which you're not concerned about?

COMMISSIONER GILINSKY: Yuh, the relative cross-sections, I think, are so powerful for plutonium production that--

MR. KELBER: As I say, until you get to the higher power plants, there's some; but in proportion it's not much; but nevertheless there's an absolute magnitude there'll be some.

Could I get the next slide, I'll summarize.

DOLLAR COSTS AND BENEFITS

- DOLLAR COSTS TO CONVERT UNIVERSITY REACTORS DEPENDS ON SCOPE OF RULE:

-- GREATER THAN FORMULA QUANTITY ONLY	$1 - 2 MILLION
-- ALL PLANTS	$13 - 14 MILLION

- COSTS RELATED TO SHUTDOWN OF UNION CARBIDE (A SOLE U.S. SOURCE OF MANY MEDICAL RADIOISOTOPES) OR NBS HAVE NOT BEEN ESTIMATED
- BENEFITS: EXPRESSED IN POLICY STATEMENT:

  A U.S. REGULATION MAY BE USED AS
  AN EXAMPLE IN OTHER COUNTRIES

The dollar costs, only--we find that it depends significantly on the scope of the rule; and that is for --if we consider only the plants that have a greater than formula quantity, the direct dollar costs in excess of current operating costs, is $1 million to $2 million.

If you consider all plants as $13 million to $14 million, these cost estimates are somewhat elastic, in the nature of all early cost estimates.

CHAIRMAN PALLADINO: Now, is that--

COMMISSIONER ASSELSTINE: That's total.

CHAIRMAN PALLADINO: Total.

COMMISSIONER ASSELSTINE: Total.

MR. KELBER: This does not include the MIT, the University of Missouri, Union Carbide or NBS.

The Union Carbide fuel has a particular cost, societal costs, which attend the fact that it is the sole source in the U. S. for a variety of short-lived radioisotopes for medical purposes.

COMMISSIONER GILINSKY: Let me ask this:

How do you subtract the amount of savings in security and so on?

MR. KELBER: No, we have not been able to get a firm figure on that. And we don't--we're not quite sure what those would be at this time.

Those vary significantly form plant-to-plant.

We have not done that yet.

COMMISSIONER GILINSKY: It seems to me that is something you want to do. In fact, one of the benefits of going to LEU is that you just have a very much reduced security problem and, therefore, you don't have to have the same number of guards and all the other paraphernalia that you would otherwise have.

MR. KELBER: My general impression is that for most of these plants, with the exception, as I say, of MIT, MURR and so on, the security costs are not in themselves a large factor; but we can look at that in some detail.

The--finally, I just haven't dwelt on the benefits because they were expressed in the policy statement; and really, this is a very abbreviated statement of what's in there, in the policy statement.

And I don't want to sell the benefits short. I simply wanted to save time.

MR. DIRCKS: I think there's one issue that maybe Harold might want to mention--whether, when they convert, whether there's a license amendment, or whether that opens it up to some procedural questions that you might want to consider in any rule?

Harold, did you want to say anything more on that aspect?

I know it was a concern expressed by you in view of the amendment situation we got into the other day; you might want to take a look at that.

MR. DENTON: We do not have an answer to the question of whether such conversion would require the offer of a hearing prior to amendment or not.

Some of the hearings on research reactors do run quite long; and it's certainly an issue to consider, and whether they make this directed conversion does necessarily require a hearing before we can approve it.

COMMISSIONER GILINSKY: It seems to me that --I think that's an important point--but whatever we do, we can't let the hearing situation drive the decision.

We ought to adjust the hearings to the needs of the situation. And if there is any place where I think a simplified form of hearing is--would be in order, I think this is it.

I don't think you need the kinds of hearings that we have in power plants where--

CHAIRMAN PALLADINO: Well, would a hearing be required before--

MR. DENTON: I think ordinarily, unless we do something unique in this case, it wouldn't surprise me to require a hearing if we make a--

MR. DIRCKS: It depends on how m ajor the change is that this rule results in.

I think we should keep it in mind and maybe we can supply you with some thoughts on that. It's something we just don't want to brush--

CHAIRMAN PALLADINO: This is a matter we might be able to deal with within the rulemaking, as proposed; and I really had in mind exploring that.

MR. MINOGUE: I might make one comment: we've tried to keep the scope of the Staff work relatively narrow; and a lot of the points that were brought up here are well outside the scope of what we are trying to do; because if the issue can be dealt with simply in terms of not using the material, we are well outside the scope of what we were trying to do.

If the issue can be dealt with simply in terms of not using the material, the other problems go away.

So we've kept this relatively narrow.

COMMISSIONER ASSELSTINE: Let me ask one other question on the licensing issue:

Is it clear that if the Commission, in effect, ordered conversion of these plants that you'd have to have a license amendment?

I mean, I certainly understand how we get into license amendment problem where a licensee comes in and says, "I want to do something that requires a change to my license."

But I just wonder if you've looked at that question: if the Commission is saying, you have to convert --to what extent does that then require an amendment to the license?

MR. DENTON: I don't know the answer to that.

Absent an order we treat it as any other license amendment; and it would be looked at from a significant hazards situation.

COMMISSIONER ASSELSTINE: Yes.

MR. DENTON: But whether or not it's done by order might be a different route.

And we don't have anyone today who could answer the question.

But as we move down this route, as Bob said, maybe we could work something into a rule in this area that would be self-executing.

But some of the hearings in this area are quite prolonged. I think we had--

COMMISSIONER ASSELSTINE: Right.

MR. DENTON: --one case that's three years now, and is still going.

COMMISSIONER BERNTHAL: Well, it seems to me though, that--and I assume this was Victor's point, that as long as you aren't shutting everything down while the hearings go on, but, rather, let the process take its course we can certainly seek to achieve the objective of conversion, and having people operating and doing research with their facilities while the process goes on, before the actual construction work the change begins.

I mean, is that what you are saying? Or--

COMMISSIONER GILINSKY: Well, I didn't really have a suggestion.

But it seems to me that there may be ways to simplify these hearings. They're talking about regulatory reform; that may be a place to apply it.

(Laughter)

COMMISSIONER BERNTHAL: And the question is: who pays for them, too?

I believe in the case of the University of Michigan, for example, they spent some years in the hearing process on their reactor; and, I suspect, at great cost to the university.

And, again, we come back to the requirement that the funding for this somehow be covered by--

COMMISSIONER GILINSKY: This may be a little overly-optimistic, but it seems to me that since the university will be moving in the direction, we would assume, that whoever is asking for a hearing would want it to move in; and the alternative is not to do--not to carry out this program, that many of these cases--I'm just assuming there will be hearings--perhaps these things will be settled without hearings.

CHAIRMAN PALLADINO: You know, it would be nice if we could do it.

MR. KELBER: The Staff has discussed among themselves, but not with our management, a number of possibilities to ease the licensing problem; because we must recall it's also a problem for the NRC Staff, and a cost to the NRC.

And we have thought of either of something like a lead plant concept where licensing one member, reviewing one member of a class--there's only about four or five classes of reactors--would stand in for all of those in that class.

Or writing into the rule, itself, tables of parameters for each class, within which a license is extended automatically.

And this will require further discussion.

I might say, since we've started the discussion, the time estimate of three months has gone up to four months.

CHAIRMAN PALLADINO: For what?

MR. KELBER: For the preparation of a final rule to send up to you.

But we believe that course of action could be done. Or at least, it's worth talking about.

I am ready now to introduce our next speaker if you want.

COMMISSIONER ASSELSTINE: Just before you do that, let me ask you one question, Charlie:

You didn't touch too much on the benefits; you said there were benefits identified in the Policy Statement.

MR. KELBER: Solely for the purpose of saving time.

COMMISSIONER ASSELSTINE: Yes.

But let me ask you one other question:

Did you look at whether there would be benefits or advantages to the universities in terms of an opportunity to make some other modifications to the plant at the time you were building the conversion, perhaps that also would be included or absorbed in the cost of conversion to the Federal Government, it would make the reactors more useful than they are now?--of substantial benefit?

MR. KELBER: This bears on the question of hearings. It's a two-edged sword.

Many of the universities--when I say "many," I mean more than three--that I spoke to individually, expressed a desire to make some changes in their plant.

And typically these are significant changes that would in fact be a major license amendment.

At the same time they want to avoid a hearing.

As far as I can see, that's having your cake and eating it, too.

And this is the problem: it's a two-edged sword.

But, yes, there certainly is an opportunity here that--for those types of changes. But I don't think that --I think one would want to consider very carefully before trying to sweep changes that significantly effect--may significantly effect safety under a rug of an issue where the safety problem is disposed of by the rule.

CHAIRMAN PALLADINO: Okay.

Who is going to speak next?

MR. KELBER: I would like to introduce now Dr. Donald Harris, of the Rensselaer Polytechnic Institute.

Dr. Harris has led the LEU Study Group and is here to go through the findings with you.

DR. HARRIS: Thank you, Charles.

May I have the first transparency, please? Thank you.

The LEU Conversion Study Group was to assess the implications of conversion of the University Research and Training Reactors to LEU fuel. And t his work was

ASSESSMENT OF THE IMPLICATIONS OF CONVERSION OF UNIVERSITY RESEARCH AND TRAINING REACTORS TO LOW ENRICHMENT URANIUM FUEL*

LEU CONVERSION STUDY GROUP

*Work supported by
the USNRC
under Contract No. NRC-04-83-179

LEU Study Group

Dr. Donald R. Harris, Chairman
Rensselaer Polytechnic Institute

Mr. R. Robert Burn
University of Michigan

Mr. Lincoln Clark
Massachusetts Institute of Technology

Dr. Thomas F. Parkinson
Virginia Polytechnic Institute

Project Officer
Dr. Charles Kelber, USNRC

supported under a contract with the NRC.

Next transparency, please?

Now, I'm here to report on the fact-finding part of this investigation:

The LEU Study Group consisted of myself, Mr. Robert Burn from the University of Michigan, Mr. Lincold Clark from MIT; Dr. Thomas Parkinson from BPI; and the Project Officer is Dr. Charles Kelber of the U.S. N.R.C.

Next transparency, please?

Now, the LEU Study Group was chosen so as to represent the considerable range in university reactors, from the high power reactors, emphasizing research, to the low power reactors, emphasizing training.

It included a member of the NEDHO organization, it included the then-current head of the Test Research and Training Reactor, TRTR, organization; and included a representative of the DOE Support Conversion Demonstration at the University of Michigan.

Next transparency, please?

The LEU Study Group assessed conversion of the 25 university reactors from HEU to LEU, that is, we did not address the NDS reactor or the other five commercial reactors licensed by the NRC.

We addressed this matter from the aspects of

THE LEU STUDY GROUP

- REPRESENTED CONSIDERABLE RANGE IN UNIVERSITY REACTORS, FROM HIGH POWER REACTORS EMPHASIZING RESEARCH TO LOW POWER REACTORS EMPHASIZING TRAINING

- INCLUDED A MEMBER OF THE NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION (NEDHO)

- INCLUDED THE CURRENT HEAD OF THE TEST, RESEARCH, AND TRAINING REACTORS (TRTR) ORGANIZATION

- INCLUDED A REPRESENTATIVE OF THE DOE-SUPPORTED CONVERSION DEMONSTRATION AT THE UNIVERSITY OF MICHIGAN

THE LEU STUDY GROUP

- ASSESSED CONVERSION OF 25 UNIVERSITY REACTORS FROM HEU TO LEU FROM THE ASPECTS OF:
    - TECHNICAL FEASIBILITY
    - FUNCTIONAL IMPACTS
    - LICENSING
    - SCHEDULING

- CONDUCTED AN LEU CONVERSION SURVEY OF ALL 25 UNIVERSITY REACTOR GROUPS

- CARRIED OUT ENGINEERING ESTIMATES BUT NO DETAILED COMPUTER CALCULATIONS. THE LATTER WERE SUPPLIED BY RERTR GROUP AT ARGONNE NATIONAL LABORATORY.

- PROVIDED DETAILED REPORT

technical feasibility, functional impacts, licensing, scheduling, and I will go through each of those in turn.

We soon became aware that more information was needed from the universities; so I wrote a letter to each of the 25 university reactor groups; and got very nice responses, both written and verbal, to supplement the written responses--we refer to his as an LEU Conversion Survey.

We carried out engineering estimates, but we did no detailed computer calcualtions. The latter were supplied by the RERTR Group, the Argonne National Laboratory.

And we provided a detailed report.

Next transparency, please?

I will very briefly provide some detailed information on a few transparencies to come, but I propose to go over them rapidly, unless there are specific questions.

And in the meantime I would like to bring out what we expect to see: there's a great range in energy.

Most have lifetime cores, although the definition of "lifetime" is a little ambiguous.

Most have plate-type fuel, however, the TRIGGERs use UZRH rod fuel.

Finally, U.C., Santa Barbara, has an aqueous

CHARACTERISTICS OF 25 UNIVERSITY REACTORS

- GREAT RANGE IN ENERGY
- MOST HAVE "LIFETIME" CORES
- MOST HAVE PLATE TYPE FUEL
- TRIGAS USE UZRH ROD FUEL
- UC SANTA BARBARA IS AQUEOUS HOMOGENEOUS
- MOST REACTORS DIFFERENT

homogeneous reactor.

The reactors that you'll see are very different.

May I have the next transparency, please?

Now, you notice that these reactors are identified as to classes: high power reactors, medium power, low power, including some very low power, TRIGGERs, Argonauts, and the aqueous homogeneous reactor.

CHAIRMAN PALLADINO: Is that Table 1?

DR. HARRIS: This is Table 1, and it brings out the location, the acronym, the docket number, and the expiration date.

Next transparency, please?

Now, this has more detail in it, and showing the amount of energy production. If we regard HEU traffic as proportional to energy production, to some extent you'll notice that the high power reactors and a couple of medium power reactors are responsible for almost all the traffic.

That is, the low power reactors, which are in some sense most vulnerable to costing considerations, as we'll see, have practically no impact on the traffic situation; although I'm the director of one of these low power reactors at RPI, and I think I share some of the questions about security.

Now, you notice one other thing from this

Table 1.1

University Research and Training Reactors with HEU Fuel

	University/Laboratory	Location	Reactor Acronym	NRC Docket	Lice Exp. Date
	Plate Type Fuel, 93% Enriched Uranium				
	High Power				
1.	University of Missouri-Columbia	Columbia, MO	MURR	50-186	2001
2.	Massachusetts Inst. of Technology	Cambridge, MA	MITR	50-20	1996
3.	Georgia Inst. of Technology	Atlanta, GA	GTRR	50-276	1994
	Medium Power				
4.	Rhode Island Nuclear Science Center	Narragansett, RI	RINSC	50-193	2002
5.	University of Michigan	Ann Arbor, MI	FNR	50-2	1985
6.	University of Virginia-UVAR	Charlottesville, VA	UVAR	50-62	2002
7.	University of Lowell	Lowell, MA	ULR	50-223	1985
	Low Power				
8.	University of Missouri-Rolla	Rolla, MO	UMRR	50-123	2004*
9.	Ohio State University	Columbus, OH	OSURR	50-150	2000
10.	University of Kansas	Lawrence, KA	BRTR	50-148	2004*
11.	Worcester Polytechnic Institute	Worcester, MA	WPI	50-134	2002
12.	Purdue University	West Lafayette, IN	PUR-1	50-182	1986
13.	Rensselaer Polytechnic Institute	Troy, NY	RPI	50-225	2003*
14.	University of Virginia-Cavalier	Charlottesville, VA	Cavalier	50-396	2002
15.	Manhattan College	Riverdale, NY	MCZPR	50-199	1984
	TRIGA, UZrH Rod Fuel 70% Enriched Uranium				
16.	Oregon State University	Corvallis, OR	OSTR	50-243	2002
17.	Texas A&M University	College Station, TX	NSCR	50-59	2002
18.	University of Wisconsin	Madison, WI	UWNR	50-156	2000
19.	Washington State University	Pullman, WA	WSUR	50-27	2002
	ARGONAUT, Plate Fuel 93% Enriched Uranium				
20.	University of California-Los Angeles	Los Angeles, CA	UCLA-R1	50-142	1980**
21.	University of Florida	Gainesville, FL	UFTR	50-83	2002
22.	University of Washington	Seattle, WA	UWNR	50-139	1989
23.	Virginia Polytechnic Institute and State University	Blacksburg, VA	VTAR	50-124	2002
24.	Iowa State University	Ames, IA	UTR-10	50-116	2003*
	Atomics International L-77, Aqueous Homogeneous, 90% Enriched Uranium				
25.	University of California-Santa Barbara	Santa Barbara, CA	UCSB	50-433	1994***

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*License renewal pending. Projected expiration date assuming license is renewed in 1983 or 198

**In hearing. License renewal date is not specified.

***Fuel possession only license.

Table 2.1

Reactor Parameters

Reactor	Power (MW)	No. of Elements Norm/Max	Element U-235 (grams)	No. of Plates	Plate Thick. (mils)	Clad/Core /clad (mils)	Control Poison
Plate-Type Fuel - 93% Enriched							
High Power							
1. Missouri-Columbia	10	8/8	780	24	50	15/20/15	Boral
2. MIT	5	24/27	510	15	70 av.	20/30/20 av	B-SS
3. Georgia Tech	5	17/19	190	16	50	15/20/15	Cd
Medium Power							
4. Rhode Island	2	30/35	120	18	60	24/12/24	Boral
5. Michigan	2	35/45	167	18	50	15/20/15	B-SS
6. Virginia-UVAR	2	20/64	190	18	50	15/20/15	B-SS
7. Lowell	1	26/30	140	18	60	24/12/24	Boral
Low Power							
8. Missouri-Rolla	0.2	27/51	170	10	60	20/20/20	B-SS
9. Ohio State	0.01	24/30	140	10	108	36/36/36	B-SS
10. Kansas	0.01	16/20	170	10	60	20/20/20	Boral
11. WPI	0.01	25/51	140	10	99	30/40/30	Boral
12. Purdue	0.001	-	170	10	100	20/60/20	-
13. RPI	0.0001	25/49	-	-	30	5/20/5	-
14. Va.-Cavalier	0.0001	-	165	12	50	15/20/15	-
15. Manhattan	10^{-7}	18/31	-	-	-	15/--/15	Cd, SS
TRIGA UZ_rH Fuel 70% w/o Enriched							
16. Oregon State	1	89/126	126	n.a.	1.47 D	1.43/.020	B-graphite
17. Texas A&M	1	90/202	122	n.a.	1.41 D	1.37/.020	B-graphite
18. Wisconsin	1	91/236	122	n.a.	1.41 D	1.37/.020	Boral
19. Wash. State	1	110/196	122	n.a.	1.41 D	1.37/.020	Boral
Argonaut H_2O & Graphite 93 w/o enriched							
20. U. Cal. - LA	0.1	24/24	140	11	70	15/40/15	Cd
21. Florida	0.1	24/24	140	11	70	15/40/15	Cd
22. U. Washington	0.1	24/24	143	11	70	15/40/15	Cd
23. VPI	0.1	12/12	266	12	80	20/40/20	Boral
24. Iowa State	0.1	12/12	266	12	80	20/40/20	Boral
Aqueous Homogeneous							
25. U. Cal. - SB	10^{-5}	Aqueous solution, 1.3 ft. diameter sphere					Cd

transparency: every case is a little bit different. Even though we have four TRIGGER reactors, 16 through 19, you'll notice that some of the numbers are different for every case.

Each case is an item of itself. Hence I would like to address a comment that Dr. Kelber made a few minutes ago. And that is that the idea of producing an envelope for a class is very appealing; because that envelope would include each of these discrete cases.

Next transparency, please.

CHAIRMAN PALLADINO: What do you mean by an envelope?

DR. HARRIS: That in the licensing process one would identify an envelope which would incllude all these cases; and that envelope would be addressed specific in the licensing.

COMMISSIONER ASSELSTINE: Is it possible to look at the issues in that way? It's essentially on a generic basis for all the reactors within a particular class.

MR. KELBER: If I can answer that?

For the lower power plants, yes; when the thermal hydraulics is not a particularly overriding issue.

For the higher power plants, it may not be. One may have to be more restrictive there.

COMMISSIONER ASSELSTINE: Because it strikes that might provide an opportunity to help ease some of the hearing problem concerns.

For example, it might well be possible to approach the generic resolution of the issues involved for a class of reactors, do it by rulemaking, rather than --where the object of the rule would be to amend the licenses of the plants involved; rather than have to go case-by-case, and face hearings in each of the individual cases, if the issue really can be solved on a more generic basis.

DR. HARRIS: That was my point.

Next transparency, please?

Now we will address technical feasibility.

The Study adopted a rather technical definition of "technical feasibility". This is the IEA definition, and it's a little bit restricted.

It says that the LEU conversion will be referred to as technically feasible if: safety margins are not lowered; fuel reliability is not lowered; preferably no loss in reactor performance; preferably no more than marginal increases in operation costs; and one that is not shown here--no major modifications to the facility.

The first two, clearly, one wouldn't want to modify safety margins or full reliability. But there's

TECHNICAL FEASIBILITY

LEU CONVERSION TECHNICALLY FEASIBLE IF (IAEA-TECDOC-233)

- SAFETY MARGINS NOT LOWERED
- FUEL RELIABILITY NOT LOWERED
- PREFERABLY NO LOSS IN REACTOR PERFORMANCE
- PREFERABLY NO MORE THAN MARGINAL INCREASES IN OPERATION COSTS

clearly room for definition in the last three items; and we chose to adopt certain definitions which may or may not be defensible:

Five to ten percent loss, for example, on reactor performance.

Next transparency, please?

COMMISSIONER GILINSKY: It seems to me the potential loss would very likely be at the higher power levels, because--

DR. HARRIS: Yes.

COMMISSIONER GILINSKY: --those are the ones that are more difficult to change over.

But they're also the ones that pose the more difficult security problems.

We've got to take both into account.

DR. HARRIS: I completely agree, and I'll come back to that later when we talk about benefits.

The RERTR program has a very nice advanced field technology program, and this transparency just kind of summarizes it.

Let me call your attention here to the fact that the plant qualification dates extend from 1984 to 1989.

COMMISSIONER GILINSKY: What do you mean by "qualification dates"?

DR. HARRIS: Well, that's a very interesting

Table 2.2 Current and Planned Fuel Technology

Fuel Meat	Clad	Uranium Density in Fuel Meat (g/cc)		Planned Qualification Dates
		Current	Planned	
UAl_x-Al	Al	1.60	2.3	January 1984
U_3O_8-Al	Al	1.30	3.2	June 1985
$UZrH_x$	Stainless Steel	0.35	3.7	January 1985
U_3Si_2-Al	Al		4.8	January 1986
U_3Si-Al	Al		7.0	June 1989

concept. I've had a lot of trouble with that--coming from the power side, I'm used to warranties on fuel.

And "qualification: is, as far as I can tell, a technical term used by the RERTR program, which I believe means it qualifies from their point of view.

COMMISSIONER GILINSKY: You mean it's available, it's accessible?

DR. HARRIS: It is accessible from their point of view.

But we have representatives from the RERTR group.

Whether a manufacturer would agree to provide fuel with a warranty is another matter; but even that--

COMMISSIONER GILINSKY: Would that be a date on which one could go out and get a contractor to manufacture the fuel and know its characteristics well enough to predict its reactor performance?

DR. HARRIS: I don't know the answer to that.

MR. KELBER: I think that is the intent.

COMMISSIONER GILINSKY: I see. Okay.

DR. HARRIS: But it is not clear to me that that intermeshing is--will automatically occur.

COMMISSIONER GILINSKY: Now, when you say January 1984, that's pretty soon. Do you think i9t's a date that's going to be met?

DR. HARRIS: They feel quite confident about that date.

I have some quotes from the program as to some of the more problematic ones, for example, the silicides; and I would be happy to discuss that or refer them preferably to Dr. Travelly or others from the program.

CHAIRMAN PALLADINO: Well, why don't we go on? We may come back to that.

DR. HARRIS: I will give an example there and that is that the TRIGGER fuel, that's the UZRHX, G.E. claims that they will sell you fuel at 3.7 grams per cubic centimeter.

There is this question that Charles raised earlier about pulse of the TRIGGER fuel.

It seems to me that, now, we've gone into this matter in considerable detail; but that the inference that one might come to is that fuel development programs have been known in the past to have difficulties, to encounter difficulites; and perhaps not actually make the target dates.

CHAIRMAN PALLADINO: Now, when we're talking about the zirconium hydride, is that 20 percent enriched?

DR. HARRIS: That's all 20 percent.

CHAIRMAN PALLADINO: All this is 20 percent.

DR. HARRIS: MAY I have the next transparency, please?

COMMISSIONER GILINSKY: Could you say something about the density of U235 atoms--comparison of this fuel--as opposed to what we're using now?

Are we basically trying to achieve the same desnity? Or more than that? Or what?

DR. HARRIS: Let me address that.

Of course, we did in the report, itself; but it's really quite simple:

One is adding an essentially nonburnable poison, U238 to HEU to make LEU out of.

And, although, as Charles pointed out, it's not anywhere near light water reactor fuel, power reactor fuel, nevertheless it's a big change; like a factor to 50-to-1 in the U238-U235 ratio, from HEU to LEU.

So this nonburnable poison costs something. You have to add some U235 to cope with it; it's about a factor of 5.

I'll take this opportunity to step ahead a little bit and say that that factor of 5 doesn't cost as much as you would think from the point of view of money, because it costs about one-fifth as much to product it, considering the number of SWUs and the feed-to-product ratio and that sort of thing.

But it does cost you in that you have to provide the U238, the nature of that extra U235 you put in; and that takes up more space in the lattice; and that's why we have an RERTR program. That is, the main difficulty with the fuel is that it is difficult--more difficult--to get the burnup and the fuels properties.

With this transparency I just want to illustrate the fact that there are a couple of ways of handling the fact that you have an additional amount of uranium per cubic centimeter in the LEU fuel.

The top sections are for HEU; the middle sections for LEU where you've been able to cope with the increased requirement for uranium pler cubic centimeter by just increasing the fuel meet dimension while keeping the coolant channel with the same dimensions as before.

Thus, with very little change in the thermal hydraulics of the system.

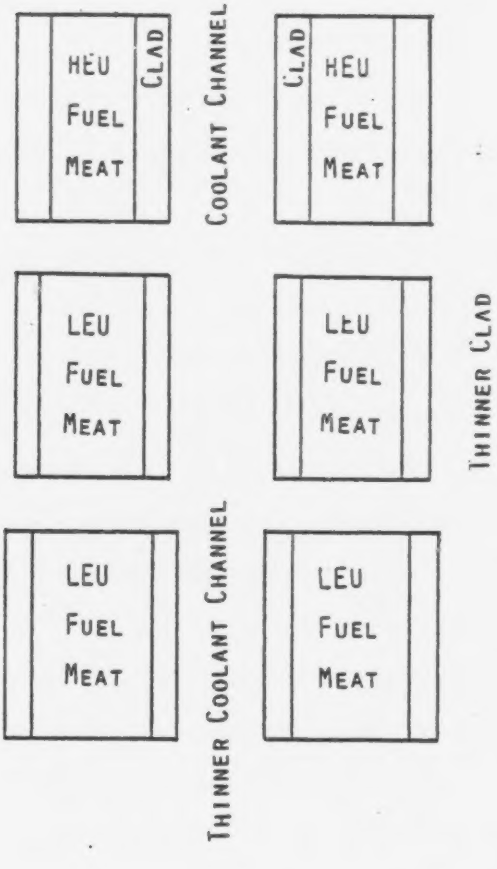
Below, however, the bottom sections refer to the situation where we had to make the coolant channel thinner in order to get the requisite amount of uranium in there. And that of course does pose a problem.

That's the problem that would be encountered by MIT and University of Missouri at Columbia, if they were to attempt to use one of the fuels that did not have the appropriate grams per cubic centimeter of uranium.

Next?

Technical Feasibility

- Plate type fuel


HEU Fuel Meat
Clad
Coolant Channel
Clad
HEU Fuel Meat
LEU Fuel Meat
LEU Fuel Meat
Thinner Clad
LEU Fuel Meat
Thinner Coolant Channel
LEU Fuel Meat

CHAIRMAN PALLADINO: Can I ask you a question on, I guess, the two top layers?

DR. HARRIS: Go back to the previous transparency, please?

CHAIRMAN PALLADINO: Yuh.

And would you be able to use the same core structure, same holding mechanism; or do you have to build a new core?

DR. HARRIS: Everything is the same. Everything is the same for the medium power reactors.

CHAIRMAN PALLADINO: For the medium power.

DR. HARRIS: For the medium power reactors.

The low power reactors, we would hope that that would be the case; but in some cases, like the RPI core, we would probably have to make modifications; and we say so in the report.

CHAIRMAN PALLADINO: How far away are we from being able to deal with the MIT and Missouri reactors?

In other words, what sort of reduction in performance would you get if you used the best fuel that's available now, or that we're talking about?

DR. HARRIS: Well, the ratio in the grams per cubic centimeter is -- you would require 8.6 grams per cubic centimeter, and the programs 7 or 7.3, depending on the circumstances.

CHAIRMAN PALLADINO: What sort of reduction in performance are you talking about?

DR. HARRIS: Well, if you~~'re going~~ to try to keep the same power density, I guess you go down about that ratio.

It gets to be a rather complicated matter, and--do you have a comment on that, Charles?

MR. KELBER: I think it's more than that, at least for these types of cores, which I've dealt with in the past, it is--there's a significant threshold; because they are such high density and high metal density cores, there's a significant amount of uranium used in that to get it to go critical; and make up the temperature defect.

And so you might be doing better to reduce the power somewhat.

DR. HARRIS: Well, that was the point.

And there is another feature, and that is, you have to refuel so often; and they already refuel about every week at the University of Missouri, Columbia, reactor; that it would perhaps be prohibitive.

CHAIRMAN PALLADINO: Is the power reduction on the order of 12-15 percent? Is that what you are implying?

DR. HARRIS: Well, we seem to have a difference--

MR. KELBER: I think you've got to do the specific calculation.

CHAIRMAN PALLADINO: In proportion to 7 to 8.

MR. KELBER: By past experience I am somewhat pessimistic. It might be a bit more.

CHAIRMAN PALLADINO: Okay.

DR. HARRIS: Next transparency, please?

Now, this transparency shows the actual changes that would be required in order to use LEU.

And as I indicated, all these cases are different, and there's an awful lot of detailed scrutiny and engineering analysis going into this.

We have two conditions:

The first condition is, with no dimensional changes.

The second is: if you use present fuel technology then you would have to make dimensional changes; like you'd have to make the fuel meet thicker, or in some cases, actually make the channel, the water channel, thinner.

Now, one encouraging thing over on the right, you'll notice there are a lot of "NCs", that means there is no change required, even with present fuel technology.

The next transparency, please?

This just finishes the, all the detailed results here.

Table 2.3 Estimate of Core Changes Required to Use LEU

Reactor	Power (MW)	Present Density (g U/cc)	If No Dimensional Changes: Required Density (g U/cc)	Fuel Tech Req'd	Date Qualified	If Present Fuel Technology^{1,2,} Must Change Parameter, From/T: Fuel Meat (mils)	Plate (mils)	No of Plates	No o Elm
Plate-Type Fuel - 93% Enriched									
High Power									
1. Missouri-Columbia	10	1.6	8.6	-	1989+		Not Feasible		
2. MIT	5	1.6	8.6	-	1989+		Not Feasible		
3. Georgia Tech	5	0.66	3.5	U_3Si_2	1986	20/39[4]	50/69	n.c.*	17/
Medium Power									
4. Rhode Island	2	0.72	3.9	U_3Si_2	1986	12/30	n.c.	n.c.	n.c.
5. Michigan	2	0.33	1.8	UAl_x	1984	20/30	50/60	n.c.	n.c.
6. Virginia-UVAR	2	0.61	3.3	U_3Si_2	1986	20/30	50/60	n.c.	20/2
7. Lowell	1	0.78	4.2	U_3Si_2	1986	12/30	n.c.	n.c.	26/2
Low Power									
8. Missouri-Rolla	0.2	0.94	5.0	U_3Si_2	1986	20/33[4]	n.c.	n.c.	27/5
9. Ohio State	0.01	0.41	2.2	$U\ Al_x$	1984	36/50	n.c.	n.c.	n.c.
10. Kansas	0.01	1.03	5.5	U_3Si	1989	20/30	n.c.	10/18	16/2
11. WPI	0.01	0.35	1.9	$U\ Al_x$	1984	40/47	n.c.	n.c.	n.c.
12. Purdue	0.001	0.25	1.3	$U\ Al_x$	now	n.c.	n.c.	n.c.	n.c.
13. RPI	0.0001		Redesign						
14. Va.-Cavalier	0.0001	0.61	3.3	U_3Si_2	1986	20/30	50/60	n.c.	-
15. Manhattan	10^{-7}	-	-	-	-	-	-	-	-
TRIGA UZrH Fuel - 70% w/o Enriched									
16. Oregon State	1	0.47	1.9	UZrH	1985	No changes, but short core life			
17. Texas A&M	1	0.49	2.0	UZrH	1985	No changes, but short core life			
18. Wisconsin	1	0.46	1.9	UZrH	1985	No changes, but short core life			
19. Wash. State	1	0.50	2.0	UZrH	1985	No changes, but short core life			

Table 2.3 Estimate of Core Changes Required to Use LEU (Continued)

			If No Dimensional Changes			If Present Fuel Technology[1,2,3] Must Change Parameter, From/To			
Reactor	Power (MW)	Present Density (g U/cc)	Required Density (g U/cc)	Fuel Tech Req'd	Date Qual-ified	Fuel Meat (mils)	Plate (mils)	No of Plates	No c Elmn
Plate-Type Fuel - 93% Enriched									
Argonaut - H_2O & Graphite - 93 w/o Enriched									
0. U. Cal. - LA	0.1	0.44	2.4	UAl_x	1984	40/60	70/90	n.c.	n.c.*
1. Florida	0.1	0.38	2.0	UAl_x	1984	40/51	70/81	n.c.	n.c.
2. U. Washington	0.1	0.45	2.4	UAl_x	1984	40/60	70/90	n.c.	n.c.
3. VPI	0.1	0.58	3.1	U_3O_8	1985	40/70	80/100	12/14	n.c.
4. Iowa State	0.01	0.58	3.1	U_3O_8	1985	40/70	80/100	12/14	n.c.
Aqueous Homogenous									
5. U. Cal. - SB	10^{-5}	0.044	0.24	New Higher Concentration	-	-	-	-	-

otes:

1) Present technology means 1.6 g U/cc for UAl_x; 0.35 for UZrH.

2) Increasing plate thickness or number of plates may cause significant change in hydraulics.

3) Increasing number of elements means larger core, hence lower fluxes, which may fail to meet criterion of no penalty in performance.

4) Plates with cores thicker than 30 mils may not be considered qualified for use in these reactors.

* n.c. means no change

I'd rather not pause on this unless there are specific questions.

Next transparency, please?

So the conclusion is, that LEU confersions are technically feasible with current fuel technology-- include five reactors, one of which is already converted.

The LEU conversions that are not technically feasible with the definition that we adopted, even with the prospective advance fuels technology, include the University of Missouri at Columbia and MIT.

Now, the Study Group was rather--felt rather strongly about this last item:

That LEU conversions that require further study before a prediction of technical feasibility can be made with confidence, includes "all others".

Now, what do we mean by that?

Just that there are so many details that are potentially different, that you just don't know. You might have a surprise on something like one-rod-stuck condition, or something of the sort.

And until those detailed calculations and analyses are done, we're just not absolutely sure.

However, we don't see any difficulties.

CHAIRMAN PALLADINO: Are you implying that the ones in the first group, and that includes University

LEU CONVERSIONS THAT ARE TECHNICALLY FEASIBLE

- WITH CURRENT FUEL TECHNOLOGY
  - UNIVERSITY OF MICHIGAN (ALREADY CONVERTED)
  - OHIO STATE UNIVERSITY
  - PURDUE UNIVERSITY
  - WORCESTER POLYTECHNIC INSTITUTE
  - UNIVERSITY OF CALIFORNIA-SANTA BARBARA

LEU CONVERSIONS THAT ARE NOT TECHNICALLY FEASIBLE

- EVEN WITH PROSPECTIVE FURTHER TECHNOLOGY
  - UNIVERSITY OF MISSOURI-COLUMBIA
  - MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEU CONVERSIONS THAT REQUIRE FURTHER STUDY BEFORE A PREDICTION OF TECHNICAL FEASIBLITY CAN BE MADE WITH CONFIDENCE

- ALL OTHERS (18)

of Michigan, that they don't require further study?

DR. HARRIS: Well, with the current fuel technology, they merely involve replacement of the LEU fuel for the HEU fuel without any change in the coolant, thermal hydrualics parameter.

CHAIRMAN PALLADINO: We remember when Penn State --we changed over to TRIGGER fuel, we had one whale of a lot of studies and interactions with General Atomics and of course, we were trying to do a few other things to update the reactor; but as I recall, there's a lot of work.

DR. HARRIS: Well, there has been some discussion that perhaps there might be some LOCA difficulties; but we don't--the conclusion of our examination was that we didn't see any difficulties.

CHAIRMAN PALLADINO: Any new procedures and retraining of people? There was in our case.

COMMISSIONER GILINSKY: Did you have to modify the configuration of the reactor?

CHAIRMAN PALLADINO: What's that?

COMMISSIONER GILINSKY: Did you have to modify the configuration of the reactor?

CHAIRMAN PALLADINO: Well--yuh, we had to do a considerable amount of work.

MR. KELBER: Well, we're talking about no modifications here.

CHAIRMAN PALLADINO: I know.

They were still being made. The question is, how much study is there, and how many changes in procedures and the like?

MR. KELBER: I think the feeling is that there's so much that can be gained from the University of Michigan experience that can be translated directly here.

CHAIRMAN PALLADINO: Yuh.

DR. HARRIS: Next transparency, please?

Functional impacts--we propose here to consider direct costs, field transportation--which I'll discuss on the next transparency; and other--the "other" including design analysis, test--

COMMISSIONER GILINSKY: Actually, the Chairman raised an interesting point:

You list the University of Michigan as having converted. Obviously, Penn State converted.

CHAIRMAN PALLADINO: Converted back in the sixties. But we also wanted to upgrade the reactor. And because of the change we had to move the control room. There were a lot of things that went on.

COMMISSIONER GILINSKY: But it was in a different era, so far as amendments and the like.

CHAIRMAN PALLADINO: Yuh.

FUNCTIONAL IMPACTS

- DIRECT COSTS
  - FUEL AND TRANSPORTATION
  - OTHER: DESIGN, ANALYSIS, ADMINISTRATION, MODIFY, TEST, LOST SERVICE-ABOUT $250,000/CONVERSION OR ABOUT 6 MILLION DOLLARS IN TOTAL

- DIRECT BENEFITS
  - REDUCED SECURITY COSTS

- SOCIETAL COSTS
  - DIVERSION OF EFFORT

- SOCIETAL BENEFITS
  - REDUCED CONCERN FOR TERRORIST ACTIVITIES

DR. HARRIS: Let me summarize the conclusions from the "other":

$250,000 per conversion, approximately, or $6 million for all.

Now, as I say, I'll come back to discuss some of these matters in more detail later.

Direct benefits: reduced security costs.

Now, that has--we have examined that in considerable length and we have not found anyone who would come forward and say, yes, they expect to reduce security costs.

This is partly because, apparently, the sabotage problem comes up; and they don't really anticipate a reduction in security costs.

Societal costs: well, there's diversion of effort from what the universities regard as their main objectives.

Societal benefits: reduced concern for terrorist activities. That certainly is an important matter for people like deans and presidents of universities and that sort.

COMMISSIONER GILINSKY: I would think so.

And not only the concern about something happening at your own facility, but if something happens anywhere, it's going to affect all these facilities.

DR. HARRIS: Absolutely.

COMMISSIONER GILINSKY: And the European facility, if anything happens it's going to affect things here just the way if something happens here, it's going to affect things over there.

It seems to me illuminating that sort of worry is--well, it's an intangible--and trying to put dollar signs on it, numbers--it's an important factor.

DR. HARRIS: Next transparency, please?

Now, we're going to go into a little more details in costs of fuel and transportation.

It's convenient to consider three options:

Option-A, all HEU fuel already produced is burned and replaced with LEU fuel at refueling time; and this would cost very little so far as fuel and transportation.

The LEU fuel, as we indicated, is just about as inexpensive as the HEU.

Option-B--

COMMISSIONER ASSELSTINE: How many plants would Option-A apply to, then? How many of the reactors?

DR. HARRIS: Five.

COMMISSIONER ASSELSTINE: Including the Michigan?

DR. HARRIS: Yes.

Option-B, same as Option-A, except that you

COSTS OF FUEL AND TRANSPORTATION

- OPTION A - ALL HEU FUEL ALREADY PRODUCED IS BURNED, THEN REPLACED WITH LEU FUEL AT REFUELING TIME
  - VERY LITTLE COST

- OPTION B - SAME AS OPTION A EXCEPT THAT INCORE HEU IS REPLACED AT TIME OF NORMAL REFUELING BY LEU FUEL AS RAPIDLY AS THIS CAN BE DELIVERED, AND UNUSED HEU FUEL (ON-SITE AND OFF-SITE) IS RETURNED TO DOE.
  - ABOUT 100 HEU FUEL ELEMENTS MIGHT BE SCRAPPED AT A COST OF ABOUT ONE MILLION DOLLARS

- OPTION C - ALL UNIVERSITY REACTORS, EXCEPT, MIT AND UNIV. OF MISSOURI-COLUMBIAM REPLACE HEU FUEL WITH LEU FUEL AS RAPIDLY AS POSSIBLE.
  - ABOUT NINE MILLION DOLLARS

burnup--if you replace the HEU at time of normal refueling, by LEU, as rapidly as this can be delivered, and unused HEU fuel on-site and off-site is returned to DOE.

Now, since it takes time to plan all this, and produce the LEU that's required, some of the HEU gets burned, even under option-B.

And this represents our best estimate as to how much would be involved: about 100 HEU fuel elements might be scrapped under Option-B, and the cost here would be about $1 million.

Option-C, all university reactors except MIT and University of Missouri, Columbia, would replace HEU fuel with LEU fuel as rapidly as possible; and the fuel and transportation estimate here is about $9 million.

CHAIRMAN PALLADINO: Let me ask you, is the University of Missouri included in A and B?

DR. HARRIS: No.

We excluded them. We concluded that that was not technically feasible by the definition we had; and then we left them out from there forever more.

Next transparency?

CHAIRMAN PALLADINO: I don't understand how we got from $1 million to $9 million?

DR. HARRIS: That includes the cores, for example, for RPI and all the other reactors, the 18-lifetime cores. Some of them aren't so little, either.

Licensing: Now, for purposes of this study we distinguished major license revision, that is, thermal hydraulics and safety and control characteristics changing substantially, and a minor amendment; that is, little change in reactor safety problems.

And I'll show you a breakdown of that in a moment.

I'm going to talk a little bit about the SAR, about the technical specifications and bases changes, if any, proposed license amendment that requires NRC action and possible public hearings.

Next transparency, please?

Safety: Now, LEU fuel does enhance safety by providing more--by providing a prompt negative Doppler coefficient, and by providing more negative void coefficient. However, it also degrades safety by a shorter neutron lifetime, a lower thermal conductivity for the fuel, smaller delayed neutron yield, plutonium from the damaged fuel, possible reduction of coolant channel dimensions.

Safety impacts depend on case-to-case to lower control rod worths, and the different access activity requirements.

Now, the only way that I think you can find out what the combined effects of all these are, are by

SAFETY

- LEU FUEL ENHANCES SAFETY BY
  - PROMPT NEGATIVE DOPPLER COEFFICIENT OF REACTIVITY
  - MORE NEGATIVE VOID COEFFICIENT OF REACTIVITY

- LEU FUEL DEGRADES SAFETY BY
  - SHORTER NEUTRON LIFETIME
  - LOWER THERMAL CONDUCTIVITY FOR FUEL
  - SMALLER DELAYED NEUTRON YIELD
  - PLUTONIUM FROM DAMAGED FUEL
  - POSSIBLE REDUCTION OF COOLANT CHANNEL DIMENSIONS

- SAFETY IMPACTS DEPEND ON CIRCUMSTANCES FOR LEU FUEL THROUGH
  - LOWER CONTROL ROD WORTHS
  - DIFFERENT EXCESS REACTIVITY REQUIREMENTS

- COMBINED EFFECTS ARE DETERMINED BY COMPUTER CODE SIMULATIONS FOR POWER BURSTS AND FOR LOCA

LICENSING

- FOR PURPOSES OF STUDY WE DISTINGUISH
  - MAJOR LICENSE REVISION: THERMAL-HYDRAULIC AND CONTROL CHARACTERISTICS CHANGED SUBSTANTIALLY
  - MINOR LICENSE AMENDMENT: LITTLE CHANGE IN REACTOR SAFETY PROPERTIES
- SAR
- TECHNICAL SPECIFICATIONS AND BASES
- PROPOSED LICENSE AMENDMENT
- NRC ACTION
- POSSIBLE PUBLIC HEARINGS

computer code simulations for power bursts, for LOCA and any other maximum hypothetical events you have in mind.

They have to be done with computer codes that are benchmarked and preferably qualified; but we don't seem to have such cases by using qualified codes--qualified in the sense of having been used in the licensing action; and, however, we do have a number of calculations done by using codes that the RERTR program, and what they show is it's pretty much of a wash.

That there's enough compensation here that the LEU fuel and HEU fuel will have rather similar properties. And I could go into a great deal of detail on that, but--

COMMISSIONER BERNTHAL: There's one point I wanted to inquire for a moment on, and that's the question of the fuel cladding.

Is there any substantial additional risk from going to these thin claddings? Is there a concern that you'd be popping the cladding more often and there would be a greater hazard then to the public?

Or are the materials essentially in hand that give you confidence equal to what you already have?

DR. HARRIS: It's been my understanding that that's part of the qualification statement; that is, that the fuel with cladding, the meet plus the cladding is part of the qualification.

COMMISSIONER BERNTHAL: So the thinner cladding is no additional significant risk to the public health and safety?

That's what I am really getting at? Is that what you are saying?

MR. KELBER: I think that answer has to be qualified in the following way:

I don't perceive that the thin cladding, per se, necessarily poses a public safety question. It might pose a site--

COMMISSIONER BERNTHAL: Operator safety question.

MR. KELBER: An ALARA question, yes.

In general, it's a functionof the power density of the plant.

For the lower power density plants you can get by with very thin cladding, the original Argonaut, for example, we have in some regions cladding as thin as 3 mills.

The--

(Laughter)

MR. KELBER: You didn't know that, huh! We're all competitors.

(Laughter)

MR. MINOGUE: You might ask Bob Burn that same question. It's my understanding on the University of Michigan demo that the clad went back to the thickness it used to have. So that problem didn't really arise.

MR. KELBER: But at higher powers, yes, there's at least a significant problem, at least in the ALARA sense.

CHAIRMAN PALLADINO: Do any of these present HEU fuel elements experience pitting over a period of time? That was one of our problems; we had pitting on the clad.

MR. KELBER: I don't know what the experience is on that.

MR. MINOGUE: It's probably more a function of your water chemistry than fuel clad.

DR. HARRIS: Next transparency, please?

CHAIRMAN PALLADINO: We got radioactive water. Excuse me.

DR. HARRIS: This transparency shows the licensing categories for LEU conversion using the minor license amendment/major license revision concept.

You will notice with the anticipation of advance fuel technology, all the lifetime cores go over to the minor license amendment mode; and with the routine fuel cycle cases, only the University of Missouri-Columbia and MIT are in the major license provision area.

Now, I must admit that when we first made this

Table 4.1 Licensing Categories for LEU Conversion of University Reactors

	Lifetime Core		Routine Fuel Cycle	
LEU CONVERSION	Minor License Amendment	Major License Revision	Minor License Amendment	Major License Revision
With Existing Fuel Technology ($UA\ell_x$ < 1.6gU/cc, $UzrH_x$ < 0.35gU/cc)	Ohio State U. U.C. Santa Barbara Purdue Univ. WPI	VPI* U. of Virginia Cavalier Georgia Tech* Iowa State* Manhattan* UCLA* U. Florida* U. Kansas* U. Missouri-Rolla* U. Washington* RPI* Oregon State U. U. Wisconsin Wash. State U.	U. Lowell U. Michigan Rhode Island	U. Virginia-UVAR Texas A&M
With Anticipated Advanced Fuel Technology (U_3 Si < 7 gU/cc, $UZrH_x$ < 3.7gU/cc)	VPI* Georgia Tech* Iowa State* Manhattan* UCLA* U. Flordia* U. Kansas* U. Missouri-Rolla* U. of Washington* RPI* U. Virginia Cavalier Oregon State Univ. U. Wisconsin Wash State U.		U. Virginia-UVAR Texas A&M	U. Missouri-Columbia* MIT*

* Assuming that safety considerations are demonstrated for LEU fuel after detailed analysis of safety parameters and hypothetical accidents.

up, we had assumed that we could count on no public hearings for a minor license amendment. So that loomed rather large in--this sort of dichotemy loomed rather large in our thinking.

We're not so sure of that any more.

COMMISSIONER GILINSKY: Now, when you said, when you put down major license revision, that--well, let's see, what role did the hearing play here?

DR. HARRIS: Well, as I say, we had perhaps incorrectly assumed that if there were no major license revision, no construction permit considered, that there would be no big hearing.

COMMISSIONER GILINSKY: In any case the table is correct as it stands.

DR. HARRIS: It's correct as it stands. The interpretation of what the significance of it is apparently olpen to question.

COMMISSIONER GILINSKY: Okay.

But what you are saying is that if one is willing to put up with major license revisions, one could handle everything but the University of Missouri-Columbia and MIT right now.

DR. HARRIS: Well, you recall, see, we have with existing fuel technology--that's the upper part of it.

COMMISSIONER GILINSKY: Right.

DR. HARRIS: So what you said is correct with the anticipated advance fuel technology.

COMMISSIONER GILINSKY: No, with existing fuel technology, if you accept major license revisions, you can--

DR. HARRIS: Oh, yes, yes.

COMMISSIONER GILINSKY: --have everything but MIT and Missouri?

DR. HARRIS: Yes.

COMMISSIONER ASSELSTINE: Is the difference between major and minor that would result principally the amount of modification to the plant?

DR. HARRIS: Yes. I defined them earlier.

CHAIRMAN PALLADINO: Would you define them again?

DR. HARRIS: I defined them earlier in that there would be, for the minor license amendment, there would be no change to the thermal hydraulics, or control parameters of the plant.

The next transparency, please?

Now, Bob Burn from Michigan is going to be talking shortly, and he will perhaps have more specific scheduling information.

I would like to comment that the demonstration conversion of the Ford Nuclear Reactor at the University

SCHEDULING

- DEMONSTRATION CONVERSION OF FNR TO LEU FUEL
  - SOMEWHAT ATYPICAL BUT ILLUSTRATIVE
- TIMES FOR CONVERSION
  - OPTION A (GRADUAL REPLACEMENT OF HEU): 6 - 10 YEARS
  - OPTIONS B AND C (ABRUPT REPLACEMENT OF HEU): 4 - 5 YEARS

of Michigan was somewhat atypical, but illustrative. The times for conversion are of some interest:

Option-A, which was the gradual replacement of HEU burning it up in place in six to ten years; but Options-B and C, which with tongue in cheek we call abrupt replacement of HEU, are still four to five years.

COMMISSIONER GILINSKY: How long did it take at the University of Michigan?

DR. HARRIS: Well, it's 72 months and it's not quite finished yet.

That's first of a kind.

COMMISSIONER GILINSKY: Is that abrupt or gradual?

(Laughter)

MR. KELBER: It started as gradual and ended up being abrupt. That was partly to help the RERTR program.

COMMISSIONER BERNTHAL: I must be missing something, because I thought Option-C, if I remember what you said, would be the lifetime cores?

DR. HARRIS: It did.

COMMISSIONER BERNTHAL: Then how did Option-A have a finite time that's not much longer? Are you telling me all those lifetime cores are sort of out of their lifetime after ten years?

DR. HARRIS: No, we just go in and we change all the lifetime cores as fast as you can get the fuel design, the SARs put together, the LEU fuel delivered, you change them all.

Option-A differeed in that if you burned-up the fuel, the HEU fuel--

COMMISSIONER BERNTHAL: Right.

DR. HARRIS: --gradually in place for the medium power cores, those five medium power cores.

MR. KELBER: Let me see if I can try:

Option-A applies simply to five reactors, one of which is already converted.

And under that schedule, of the four remaining reactors, they would replace their existing HEU fuel with LEU fuel as it's burned up.

COMMISSIONER BERNTHAL: Okay.

MR. KELBER: Option-B and C says you take out all the HEU as fast as you can, and replace it with LEU as fast as you can for all the reactors.

COMMISSIONER BERNTHAL: That's right. I'm sorry.

DR. HARRIS: Now the time requirements for Options-B and C are the items that I mentioned earlier. There's one additional.

May I have the next transparency, please?

This transparency shows the manufacturer's capability; and you can see the manufacturers have a good

Table 5.5 Research Reactor Full Core Capacity and Annual Fuel Use

		Routine Refueling Cycle Costs		
	Lifetime Cores	Full Core	Annual Use	Manufacturer's Annual Capacity
Plate Type Fuel				
Number of Elements	269	152	102	150
Number of Plates	2,806	2,712	2,256	2,700
TRIGA Rod Fuel				
Number of Rods	290	90	20	600

deal of capability. We don't really anticipate much of a problem there.

However, they have asked for a certain amount of lead time; and it might be fairly expensive, also, to produce special cores that would be a little bit different from the norm.

COMMISSIONER GILINSKY: Who are the manufacturers now?

DR. HARRIS: Babcock & Wilcox for the plate type fuel, if you limit yourself to U. S. manufacturers; and G.A. for the rod type TRIGGER fuel.

Next transparency, please?

COMMISSIONER GILINSKY: When you said the U.S. manufacturers, where else do they get them?

DR. HARRIS: The New Camen (phonetic) in Germany and Zirca (phonetic) in France, I imagine would be happy to supply fuel.

CHAIRMAN PALLADINO: On that chart you just took off, that is available right now?

DR. HARRIS: Yes. That's my understanding.

CHAIRMAN PALLADINO: And are these capacities annual capacities?

DR. HARRIS: Yes.

CHAIRMAN PALLADINO: Okay.

DR. HARRIS: Now, I would like to finish up with this one:

Table 3.3 Estimated Costs for LEU Conversion Options

LEU Conversion Option	Number of Reactors	Costs of Fuel & Fuel Shipment	Other Costs	Total Costs
A	5*	Small	$1.25M	$1.25
B	5*	$1M	$1.25M	$2.25
C	23	$9M	$6M	$15M

* University of Virginia-UVAR, University of Lowell, Rhode Island Nuclear Science Center, Texas A & M University, University of Michigan (already converted).

This shows the total cost under the three conversion Options-A, B and C, the number of reactors that are affected and identifying them down below; and the new things is the total cost over on the right--$1.25 million for Option-A, $2.25 for Option B, and $15 million for Option-C.

Thank you.

COMMISSIONER GILINSKY: Would you have a slide on the degree of the radiation in the fuel? You talked about that a few moments ago.

DR. HARRIS: I didn't get a slide made up.

COMMISSIONER GILINSKY: Do you have a reference in the report?

DR. HARRIS: This is to the question of how many are self-protecting?

COMMISSIONER GILINSKY: Right.

DR. HARRIS: Actually, that piece of information doens't appear in the report.

COMMISSIONER GILINSKY: That's what I thought.

DR. HARRIS: Right.

The formula quantity was there.

COMMISSIONER GILINSKY: Um-huh.

DR. HARRIS: But not the question of--and the amount of fuel on hand; but not the question of--as to which category.

COMMISSIONER GILINSKY: It would be useful, I think,--

DR. HARRIS: We can get that information for you easily.

COMMISSIONER GILINSKY: Okay

And not just how many are over the 100 level, but in fact, what the levels are, roughly speaking.

DR. HARRIS: You recall, we had concluded on the basis of discussions with the plant people, themselves, that they didn't anticipate any benefits from this.

Now, this may be a questionable conclusion. But that was their conclusion.

CHAIRMAN PALLADINO: Okay, thank you very much.

COMMISSIONER GILINSKY: A fine presentation, fine report.

CHAIRMAN PALLADINO: I guess we go now to Mr. Burn.

MR. KELBER: I would like to introduce Mr. Robert Burn, University of Michigan. He is a member of the LEU Study Group in addition to having been in charge of the changeover of the reactor; and he is going to tell you what he went through and try and respond to your questions on that.

MR. BURN: I'm Bob Burn, I'm the manager of the Ford Nuclear Reactor, University of Michigan.

May I have the first overhead, please?

What I have here--this exactly follows my set of slides, is a breakdown of the major categories of the work we had to perform to convert the Ford Nuclear Reactor to low enriched uranium.

Initial program planning, the preparation of the Safety Analysis, License Amendment, core physics calculations--

COMMISSIONER GILINSKY: Could you say how you got into this? Was this your idea or someone else's?

MR. BURN: In a way.

Probably five or six years ago--every year the research reactors in the United States have a national organization called the Training Test and Research Reactors --we meet once a year. And we had a meeting at MIT.

And at that time representatives from the Department of Energy came and talked about the whole conversion process. The Carter Administratin was interested in reducing traffic of HEU fuel; and they asked if anybody would be willing to volunteer to be the first U. S. reactor?

And I said: by all means, we volunteer. And that's how we got started.

And I thought, frankly, that it would be a good learning exercise, independent of the value of HEU versus

USNRC Presentation - LEU Conversion Schedule

Ford Nuclear Reactor LEU Conversion Tasks, Calendar Times, Man Hours, and Additional Costs

	Task	Calendar Time (mo)	Man Hours (hr)	Additional Costs	
				Cost ($)	Description
1.	Initial Program Planning	3	120	0	
2.	Safety Analysis and License Amendment	36	600	5,000	Word Processing, Travel
3.	Core Physics Calculations	23	4,000	10,000	Computer Use
4.	Thermal Hydraulics (Not Required)				
5.	Plat Engineering Modifications (Not Required)				
6.	LEU Fuel	27	200	DOE	
7.	Training	6	80	0	
8.	HEU Fuel	8	80	50,000	Spent Fuel Shipments
9.	Experimental Verification of LEU Fuel	18	320	10,000	Instruments
		TOTAL	5,400	$75,000	

LEU, that it would be good for our facility, good for our nuclear engineering department.

COMMISSIONER GILINSKY: Has it turned out that way?

MR. BURN: It's not as simple as people might make it out to be, because a lot of the computer codes that exist are really geared to power reactors; and power reactors don't have the thermal leakage, thermal neutron leakage; and we're such a small core that modeling that is not as simple and straightforward as you might think.

And so we spent a lot of time and a lot of money on buying codes to fit small reactors.

As a matter of fact, I couldn't volunteer the University of Michigan for this, but one possibility is that the core analysis, which is a very big effort, conceivably we could do a lot of the work for the other universities involved; because we've done it already, and the codes are ready to be used.

So I am not saying that the university would be willing to do that, but I wouldn't be surprised if they would.

COMMISSIONER BERNTHAL: How do your capabilities today now compare with what they were before conversion?

MR. GURN: For all practical purposes, no difference at all.

What has happened is that as a result of putting more uranium-238 in the core, you get greater absorption; so that the overall energy spectrum of neutrons tends to lean toward the higher energy neutrons, a harder flux.

So you get more fast neutrons that leak out of the core and get thermalized and then go to our beam ports for spectrometer type work.

So that the average energy of neutrons coming out through these beam ports is a little bit higher than it used to be.

But honestly, you can measure it, but it's a very significant effect on our facility.

But we don't specialize in spectroscopy. Now, some of the other facilities where every neutron is critical might have more of a problem. I can think of NBS and Missouri and MIT in particular where that kind of thing is more important.

But for the kind of work we do, the impacthas been negligible.

COMMISSIONER BERNTHAL: You don't do much in the way of routine irradiations such as thermal fluxes and primary considerations?

MR. BURN: Yes, we do. We produce a lot of medical isotopes.

COMMISSIONER BERNTHAL: How much is the thermal flux down?

MR. BURN: About 10 percent.

But, see, it just means you irradiate for 10 percent additional time.

So it hasn't been much of an impact at all.

Other items I have listed here--hydraulics and plant engineering modifications--in fact were not required at our facility.

What we essentially did was we did thin our clad.

Now, we had a plate that's 60-thousandths of an inch thick, we had fuel meet in the middle that was 20-thousandths; and we had 20-thousandths clad on the side.

We increased the thickness 30-thousandths and reduced the meet thickness to 30-thousandths, reduced the clad thickness down to 15.

And so that's--that was one of the ways we accommodated it.

And the other thing is that we had very low uranium loading to begin with. We've been talking about relative densities here: our uranium loading was .3 grams of uranium per cubic centimeter of fuel meet.

All we had to do was go up to 1.6, and that was the limit of existing technology.

MIT and Missouri have been using that for quite some time. So we didn't have to rely upon any advanced fuel.

And there are a number of other reactors like ours who wouldn't have to--

COMMISSIONER BERNTHAL: So your density is now what MIT and Missouri have had for some time?

MR. BURN: Yuh, we're in the upper limit of existing technology.

So that's another reason why it was easy for us to convert. And I think that's one of the reasons why Argonne asked us if we would be willing to volunteer.

CHAIRMAN PALLADINO: What kind of fuel did you convert to?

MR. BURN: Uranium-aluminum-alluminide, FULAX, as we call it; that's UAL2, UAL3--

CHAIRMAN PALLADINO: With alluminum cladding?

MR. BURN: Yes.

And the other items are associated with LEU fuel itself, training, HEU fuel, and then experimental verification of the core conversion.

And under that calendar time listed I'm going to show you a time task chart laid out:

Manhours, you can see the total effort on our part was a total of 5,400 manhours.

That does not include a lot of additional analysis that was done by our nuclear engineering department, sponsored by Argonne.

But that work was really not directly related to our core conversion. It was benchmark work and verification of codes and so forth, so that it wouldn't be fair to include that time and cost as part of this.

CHAIRMAN PALLADINO: You mean it would not have had to be done?

MR. BURN: It would have to be done to verify the codes, but now that kind of work would apply to every other reactor; so it wouldn't have to be done for future conversion.

And then additional costs here are listed. Those are in addition to the manhour costs.

And the biggest single item for us as initial cost is the shipment of a spent HEU fuel; and that cost probably has doubled over the last few years. It would probably be more like $100,000 for us to ship out the HEU fuel that we have on-site, as a result of the conversion.

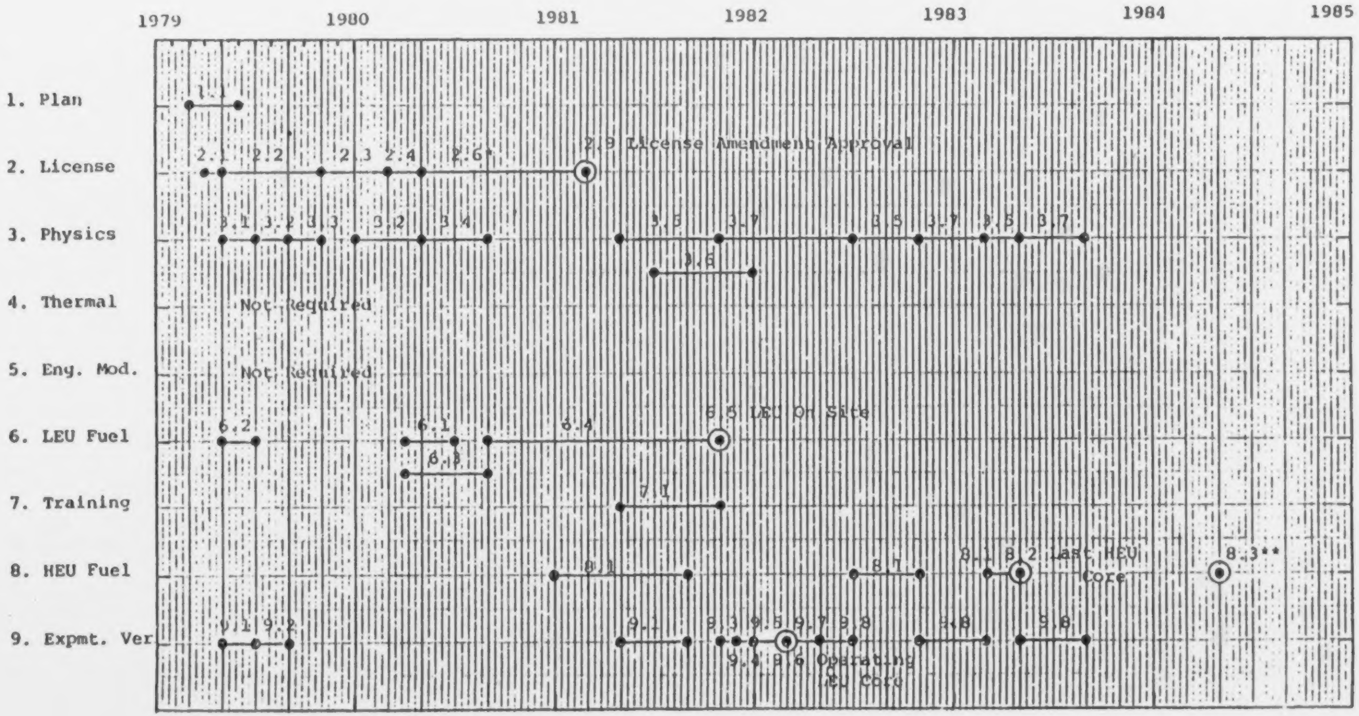
Next slide, please?

This is a schedule, and we don't have to go into it in great detail.

But if we look at the items I listed here, are

USNRC Presentation-LEU Conversion Schedule 2 of 9

Ford Nuclear Reactor LEU Fuel Conversion Task-Time Schedule



* Included request to increase on site contained U235 from 16.1 to 25 Kg.

** Some fresh HEU still on site

laid out here horizontally.

Let's just look first at item 2, which is the license amendment:

That total process took about two years.

Can we go to the next slide, please?

And this is a breakdown of the details of that. You can see it's the amendment preparation, safety analysis preparation with all of the parts of that; submittal to the NRC; getting the review back; responses.

And you can see items 2.7 and 218 there with the asterisks, are public hearings. At our facility we didn't have to have public hearings. It's UCLA who has had this prolonged public hearings process in their license renewal--because our amendment did not involve any physical changes in the reactor--there were internal plate changes--but the elements physically outside were the same, the loads to the core were identical; heat generation identical.

We had what we call a minor license amendment, and there were no public hearings associated with our conversion. That also made it very easy.

And then final approval.

So that whole process took us about a year to do that. And we wouldn't start on manufacturing fuel until that process were done and we actually had a license

Research Reactor LEU Conversion Tasks

	Task	Calendar Time (mo)	Man Hours (hr)	Estimated Cost ($)
1.	Initial Program Planning	3	120	0
	1.1 Planning, preparation, and scheduling			
2.	Safety Analysis and License Amendment	36	600	5,000
	2.1 License amendment preparation			
	2.2 Safety analysis preparation			
	2.2.1 Fuel and materials historical data			
	2.2.2 Core physics			
	2.2.3 Core thermal hydraulics			
	2.2.4 Plant engineering modifications			
	2.2.5 Comparison of HEU and proposed LEU cores			
	2.2.5.1 Reduction in safety margins			
	2.2.5.2 Surveillance of safety margin limits			
	2.2.6 Design basis event and accident analysis			
	2.3 Submittal to NRC			
	2.4 Initial NRC review			
	2.5 Responses to NRC review questions			
	2.6 Final NRC review			
	2.7* Public hearing process			
	2.8* Intervenor questions and responses			
	2.9 License amendment approval			

*Required for a major license revision, but not for a minor license amendment.

amendment to work on the fuel.

Next slide, please?

USNRC Presentation - LEU Conversion Schedule

Research Reactor LEU Conversion Tasks (Continued)

	Task	Calendar Time (mo)	Man Hours (hr)	Estimated Cost ($)
3.	Core Physics Calculations	23	4,000	10,000
	3.1 Lattice and cross section calculations			
	3.2 Generic core model development and calculations			
	3.3 Safety analysis support data			
	3.4 External core calculations			
	3.5 Verification of core models against HEU core			
	3.6 Modification of lattice and core models			
	3.7 Verification of core models against HEU core			
4.**	Thermal Hydraulics	Not Required		
	4.1 Thermal hydraulics analysis			
	4.2 Safety analysis support data			
	4.3 Thermal hydraulics modelling and testing			
5.**	Plant Engineering Modifications	Not Required		
	5.1 Planning			
	5.2 Design			
	5.3 Safety analysis support data			
	5.4 Procurement			
	5.5 Fabrication			
	5.6 Installation			
	5.7 Testing			

**Required for fuel and system modifications that alter core flow, heat transfer, and fuel temperatures.

If you look at the calculations in Item 3, those extended, as you can see, starting in '79, lasting through '83, roughly over almost five years. In fact, I think future conversions of other reactors would not have to take that long and the reason it took as long in our case is because we were a benchmark.

CHAIRMAN PALLADINO: Did you go back to an earlier slide?

MR. BURN: Yes, I am sorry. I flipped back and forth between these explanations and putting this overall schedule back up.

CHAIRMAN PALLADINO: Okay.

As you see, Items 4 and 5, the thermal hydraulics and engineering modifications were not required.

Next slide, please. This is a breakdown of the core produce calculations and fundamentally they would involve what you would expect. You have to get the basic -- and cross-section information associated with the core, then coming up with a specific core model, and getting the verification.

We verified this calculation versus our present HEU core at the time. That is, we took measurements in the HEU core and verified the models we developed against those, and in addition to that -- which is not listed here -- we had to do things like control rod calibrations and so forth.

The next slide, please.

And then we get into Item 6, which is the work associated with the LEU fuel and then the HEU fuel, and finally the experimental verification. Those are stretched out, as you can see, over roughly a five-year period.

Next slide, please.

And to look at those in a little bit of detail, once we got the license amendment approved, then we went through preparing the specifications and the drawings for the LEU fuel, going out for the bidding process. And interestingly enough, our fuel was provided by Circa and Neuchem. The LEU fuel in our core came from France and Germany.

The next LEU fuel we get, which will be next year, will be coming from Babcock and Wilcox. So, there are these three suppliers. And then, calculational confirmation of the design. That is, we had to verify the fuel as we specified it, it was going to perform as we expected. We did a calculation first and the procurement fabrication process. That whole process, again, took another couple of years.

HEU fuel, we did verification of the current HEU cores at the time, again start calculation, and then once we got Item 9, once we got the LEU fuel inhouse, we initially put one element in the core; then we put a row of

USNRC Presentation - LEU Conversion Schedule

Research Reactor LEU Conversion Tasks (Continued)

	Tasks	Calendar Time (mo)	Man Hours (hr)	Estimated Cost ($)
6.	LEU Fuel	27	200	DOE
	6.1 Fuel specifications and drawings			
	6.2 Safety analysis support data			
	6.3 Calculational confirmation of fuel design			
	6.4 Fuel bids, procurement, and fabrication			
	6.5 Fuel delivery			
7.	Training	6	80	0
	7.1 Staff training; fuel and facility modifications			
8.	HEU Fuel	8	80	50,000
	8.1 Core physics measurements on HEU core			
	8.2 Last HEU use in core			
	8.3 Last HEU shipment			
9.	Experimental Verification of LEU Fuel	18	320	10,000
	9.1 Planning			
	9.2 Safety analysis support data			
	9.3 Single element insertion			
	9.4 Multiple element insertion			
	9.5 Critical loading experiment			
	9.6 Initial full LEU core			
	9.7 LEU core physics measurements (In core and ex core thermal and fast fluxes, reactivity coefficients)			
	9.8 Verification of LEU core analysis			
	TOTAL		5,400	$75,000

elements, four elements in the core. And our original intent was to undergo a conversion by replacing LEU as it was burned up with an HEU element. That is, we take one LEU out, an HEU out and put an LEU in its place. But because our nuclear engineering department and Argonne National Lab was interested in whole core measurements, we then decided that we would do a whole core conversion.

So, we started out as Option A, I guess it was, in the option lay-out and finally ended up being in an abrupt conversion. So, that's the way we stand. We have a complete LEU core conversion right now.

And in fact, we have gone back and forth, put the whole HEU core back in and in fact the whole LEU core.

CHAIRMAN PALLADINO: How much disruption in terms of time was there to your operational --

MR. BURN : To be honest, probably two months. We did it over the Christmas period, December and January. It was not a big imposition on the work.

And again, we used some of this in our reactor laboratory. We had a reactor laboratory in January. The whole critical experiment, whole core critical experiment, we did as our reactor laboratory class.

And then, the final verification of the rod worth and so forth against the core as it was --

Next slide, please. And the next slide, please.

6 of 9

USNRC Presentation - LEU Conversion Schedules

University Research and Training Reactor Core and Amendment Categories

Lifetime Core - Minor License Amendment

Lifetime Core - Major License Revision
(Construction Permit)

Routine Refueling Cycle - Minor License Amendment

Routine Refueling Cycle - Major License Revision

Now, this is just to compare our conversion with the categories we defined here. Breaking this slide here in half, on the left you have the type of core, what we call the lifetime core which applies to 18 of the reactors of our 25 that we studied. And those that have routine refueling, which applies to seven. And on the right are those that require minor amendments and major amendments. A major amendment, again, is something that involves theremal hydraulic changes.

Next slide, please.

As those are broken down, starting on the left, we have lifetime cores and those that undergo routine refueling and then major and minor amendments, and then those that can use current fuel technology versus advanced fuel technology.

So, if we run through that whole arrangement, we see that four reactors have lifetime cores, would require minor amendments, and can use current fuel technology and 14, in that same category, would require advanced fuel technology. And the conversion of those reactors would take about four years. That would just be the realistic time of preparing and submitting, and getting approved a license amendment and then specifications and delivery of the fuel, core physics and so on and so forth.

CHAIRMAN PALLADINO: This doesn't mean that much

USNRC Presentation - LEU Conversion Schedule

LEU CONVERSION SCHEDULES BASED ON OPERATING CYCLE AND TYPE OF LICENSE AMENDMENT

Operating Cycle	License Amendment	Fuel Technology	Number of Reactors	LEU Conversion Schedule (Initial Planning to Last HEU on Site)
Lifetime Core	Minor	Current	4	Conversion 4 years
		Advanced	14	
	Major	Current	0	
		Advanced	0	
Routine Refueling	Minor	Current	3	Conversion 4 years Fuel Cycle 2-5 years
		Advanced	2	
	Major	Current	0	Public Hearings Conversion 4 Years 1 year Fuel Cycle 2-5 years
		Advanced	2	
		TOTAL	25	

time -- it would not be disrupted that long.

MR. BURN: No. People have tried to make their own estimates. We are the only ones, of course, that have experienced this. People have tried to make their own estimates on how much disruption would occur, and we have had estimates from the 25 reactors involved anywhere from hours to a couple of months, up to about six months. That was the --

CHAIRMAN PALLADINO: Well, I heard arguments used that say there is disruption to the research program, people couldn't get out papers and what not. It sounds that that was not a major problem.

MR. BURN: I would say it really depends upon a facility. I would think at the smaller facilities, these 18 on the top here, I would be very surprised if it had much of an impact.

CHAIRMAN PALLADINO: Not much.

COMMISSIONER GILINSKY: It sounds like you got something to write papers about here.

CHAIRMAN PALLADINO: Yes. I remember --

(Simultaneous conversation.)

(Laughter)

CHAIRMAN PALLADINO: But people that are using it as an irradiation facility, they are the ones that suffer.

MR. BURN: Who do spectroscopy work. I guess a conversion of the National Bureau of Standards reactor would have a very significant impact, I would think.

All right, so we are talking --

CHAIRMAN PALLADINO: They do lose some of their reference data.

MR. BURN: Yes, that seems to be a big concern among a lot of the reactors that had to spend an awful lot of time doing foil activations and so forth to characterize their core, knowing exactly what the flux was at a given location -- especially the smaller non-power reactors who do not change their fuel. That is, they effectively have lifetime cores and very little fuel shuffling goes on.

In a case like ours, we almost have to re-characterize before every time we do a significant fuel reloading. So, it's not as important for us.

At any rate, I think four years is, if anything, is an underestimate. That is, I don't think it is being generous in trying to pad with time. I think four years is, if anything, a slight underestimate of the time it would require for a single reactor to undergo this full core conversion.

And then, if we go on to those seven reactors that have routine refueling cycles, we have basically the same time for conversion but for five of the reactors, which included ours, if we did it by routine refueling -- that is, you insert the LEU at the time you pull out an HEU element, the in-core residence time for fuel elements ranges from two to five years for those reactors. That is, from the time an element goes into the core and is shuffled around through its pattern, and finally comes out, it ranges from two to five years, depending upon the duty cycle of the reactor. Our reactor is two years.

So that adds, if conversion is done that way, adds the possibility of going to nine years for the total process from the time you begin to the last HEU on site.

Then, finally, the same thing is true for MIT and Missouri if they were able to convert -- they put in another year for public hearings and that may be a gross underestimate of the public hearing time, too.

CHAIRMAN PALLADINO: Have you found that handling shipping casks at a university a problem? I read somewhere where one of them said that it would cost $25,000 --

MR. BURN: Yes. We had a ten-ton crane, and most of the reactors don't have a crane any larger than ten tons. And today there is not a cask which is below ten tons.

CHAIRMAN PALLADINO: So, what you --

MR. BURN: We had to upgrade to 15 tons and some eight years ago that cost us $25,000. So, that is a problem at any of the facilities. The whole cask situation could be a problem because right now there are only three casks, General Electric has two rental casks out at San Jose, and the Battelle Memorial Institute in Columbus, Ohio has one cask called the BMI-1.

There are two casks being refurbished for the Department of Energy now, but they are in the licensing process and there is a possibility that they may never be able to be licensed because of heat shield problems and that sort of thing. That is up in the air right now.

And the cost of a cask, just the cask rental itself, is about $15,000 for a shipment. So, by our standard --

COMMISSIONER GILINSKY: Where does this fuel go, the spent fuel go?

MR. BURN: Most of us send it to South Carolina.

COMMISSIONER GILINSKY: Savannah River?

MR. BURN: To Savannah River. There was an interest in having it shipped to Idaho for the higher burn-ups because somebody was running an experiment with the new Tripton 85, and so some reactors have been asked to shipped to Idaho. Missouri, for example, shipped to Idaho.

We still ship ours to South Carolina.

COMMISSIONER GILINSKY: How often do you send a shipment?

MR. BURN: It's roughly -- well, one could do it about once a year, we couldn't with our duty cycle. We usually don't do it once a year, we ship maybe two shipments every two years. As a result of this conversion we have right now 72 elements on site, self-protecting, but that we need to ship out.

Now, some of those came from our routine operation, but about 45 to 50 of them came from this whole core conversion. That is a real concern because we are talking roughly $25,000 a shipment, seven shipments, $275,000 which for us is a lot of money.

CHAIRMAN PALLADINO: Didn't you have to make shipments before the modification?

MR. BURN: Yes.

CHAIRMAN PALLADINO: Well, what did you do with crane problems then?

MR. BURN: Yes. Some time ago, it was paid for by the Department of Energy, just as our cost --

CHAIRMAN PALLADINO: But the upgrading of the crane was not necessarily related to the conversion.

MR. BURN: Oh, not at all.

CHAIRMAN PALLADINO: Thank you.

MR. BURN: It used to be that DOE paid for fuel shipments. Now, we pay for our own fuel shipments. So, I would say that of these 72 elements, 45 to 50 are a direct result of the conversion, which is $100,000.

The next slide, please.

These are -- if you were considering what would be

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USNRC Presentation - LEU Conversion Schedule

Bases For Scheduling LEU Conversions

Reactor Relicensing

Refueling Cycle

Reactor Utilization Schedule

Type of Conversion

Fuel Fabrication Capabilities

Spent Fuel Shipping Cask

the basis for conversion, in other words, you could use reactor relicensing dates and say, "Well, we ought to schedule the conversion process coincident with reactor relicensing," or work it into the regular refueling cycles of the reactors or other things, such as the utilization schedule of the reactor, the type of conversion and fuel fabrication capabilities of manufacturers and so forth.

I looked at that to some extent and I could not find any good pattern to fit in the conversion process with license renewal and so forth. That is, the dates just didn't fit. So, my feeling is, if conversion is required that it ought to be just done in an orderly way, independent of relicensing dates or anything else. In other words, just sit down and say, "What is an orderly process for doing this which is within the fuel fabrication capabilities of the manufacturers and the availability of spent fuel shipping casks," and so forth. That is, there is no nice, neat, clean way to do it. This should be done in an orderly way.

The next, the last slide, please?

These are some of the concerns of conversion in terms of scheduling. The magnitude of the license revision because of potential public hearing, and any major engineering modifications to the facility which would involve a significant cost to the facility.

Most of the reactors -- I shouldn't say "most" --

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USNRC Presentation - LEU Conversion Schedules

Potential Conversion Problem Areas

Magnitude of License Revision

Public Hearings

Major Facility Engineering Modifications

Conversion by Following Routine Refueling Cycle

Fuel Manufacturer's Capacity

Spent Fuel Shipment Cost and Cask

Core Physics Analyses Costs and Man-Hours

New Fuel Costs

all of the reactors would like to convert by following their routine refueling cycle, allowing these extra years, essentially, rather than an abrupt conversion.

The fuel manufacturer's capacity, which does not seem to be a problem at all, both Babcock and Wilcox and GA seem to have plenty of capability to manufacture the fuel. Spent fuel shipment cost in casks may be a concern, and core physics analyses and costs and man-hours, a lot of time goes into that work, so that may be a problem for the smaller reactors expecially. And then bearing the new fuel costs themselves.

That concludes my presentation.

CHAIRMAN PALLADINO: Any other questions?

COMMISSIONER GILINSKY: No, I just want to thank you for the presentation.

MR. BURN: Thank you.

COMMISSIONER GILINSKY: It was good of you to take a lead in this area.

CHAIRMAN PALLADINO: Thank you very much.

I am going to suggest we take a ten-minute break.

COMMISSIONER GILINSKY: I like that idea.

CHAIRMAN PALLADINO: What?

COMMISSIONER GILINSKY: Good.

CHAIRMAN PALLADINO: Then we will return and continue.

(Whereupon, at 3:40 p.m. a ten-minute recess was taken.

CHAIRMAN PALLADINO: I wonder if we might reconvene. Is Mr. Turinsky here?

MR. KELBER: Yes, sir. I would like to introduce now Professor Turinsky from North Carolina State --

CHAIRMAN PALLADINO: Please, may we have your attention?

MR. KELBER: -- who is here representing the Nuclear Engineering Department Heads Organiation.

MR. TURINSKY: Thank you for this opportunity to speak before you on this important matter.

The Nuclear Engineering Department Heads Organization or NEDHO -- I hate to introduce another acronym into this nuclear community but I'll do it -- is an organization made up of exactly what its title sounds like, and that is the chairman and heads of the various nuclear engineering departments or programs arcund the United States, and we have about 60 members of the university reactors that would be impacted by this proposed rule, are represented in NEDHO.

Could I have the next overhead, please?

We basically, I basically got two sources of input into the statements I am going to make, one is to the LEU Study Group questionaire that Don Harris had sent out, which was an extensive questionaire, mainly technical, not

UNIVERSITIES' VIEWS OF HEU TO LEU CORE CONVERSION

NUCLEAR ENGINEERING DEPARTMENT HEADS ORGANIZATION
(NEDHO)

PRESENTOR: PAUL J. TURINSKY
CHAIRMAN, NEDHO
(NORTH CAROLINA STATE UNIVERSITY)

DECEMBER 19, 1983

SOURCES OF NEDHO MEMBERS' INPUT:

- LEU STUDY GROUP QUESTIONNAIRE
- RESPONSES TO LEU STUDY GROUP RECOMMENDATIONS AND MARCH 1, 1983 MEMO FROM J. E. ZERBE TO COMMISSIONER AHEARNE

so much policy oriented. I went through those various responses and tried to get some sort of reading of what our members have in mind.

The other thing that I did several weeks ago was, I sent out the LEU Study Group recommendations, that is about the first nine pages of that report, and also sent out the March 1 memo of Zerbe to Commissioner Ahearne which is a proposed policy statement on that.

The members responded to those pieces of information to me in writing, mainly by phone calls because of the shortage of time.

The next overhead, please.

Now, one of the things, we being NEDHO, the university folks are trying to understand why you want to do this to us.

COMMISSIONER GILINSKY: We are going to do it together.

(Laughter)

MR. TURINSKY: It's the "doer" and the "doee" or something here.

(Laughter)

COMMISSIONER GILINSKY: At least it will benefit to the benefit of everybody else.

MR. TURINSKY: Okay. What we did was, we went to this Zerbe memo of March 1, 1983 and I extracted a few

MOTIVATION FOR US HEU TO LEU CORE CONVERSION

BASIS FOR INTERPRETATION: J. E. ZERBE MEMO OF 3/1/83 TO COMMISSIONER AHEARNE (PAGES 5 AND 6)

- THE PRINCIPAL CONCERN OF US POLICY WITH RESPECT TO HEU USE ABROAD IS THE THREAT OF NATIONAL DIVERSION.
- THE GOAL OF US POLICY IS TO STOP ALL INTERNATIONAL TRAFFIC OF HEU.
- THE US SHOULD ADOPT A DOMESTIC POLICY ON HEU REDUCTION COMPARABLE TO ITS OVERSEAS POLICY TO SET AN EXAMPLE. OTHERWISE, THE US WOULD BE ACCUSED OF TRYING TO GAIN AN ADVANTAGE IN NUCLEAR TECHNOLOGY AND RESEARCH.
- CURRENT US PHYSICAL PROTECTION REGULATIONS ARE SUFFICIENT TO COUNTER DOMESTIC THREATS AND THAT THE PRIMARY PURPOSE OF THE INITIATIVE IS TO ENCOURAGE CONVERSION OF FOREIGN FACILITIES.

key words here, and I gather from the earlier discussion that all the Commissioners here perhaps support the words that were in this memo, but let me go through it.

The first bullet is basically the principal concern of U.S. policies with respect to HEU use abroad from a national diversion viewpoint.

COMMISSIONER GILINSKY: Well, let's see, that isn't clear.

MR. TURINSKY: That is what was in the NRC memo.

COMMISSIONER GILINSKY: I know, but that doesn't mean it's gospel.

MR. TURINSKY: No.

(Laughter)

MR. TURINSKY: It is our basis of understanding of this.

COMMISSIONER BERNTHAL: Don't believe everything that comes out.

(Laughter)

COMMISSIONER GILINSKY: Just checking to see whether you are paying attention.

(Laughter)

CHAIRMAN PALLADINO: This is the gospel according to St. Zerbe.

(Laughter)

COMMISSIONER GILINSKY: I would say it depends where it is. In some countries it's in places where national diversion is highly impossible, and other places, I suppose, you are very concerned.

But certainly, the theft by others in countries is a big concern.

MR. TURINSKY: Let me summarize all of those bullets up there. Our understanding is that we in the U.S. are basically setting an example for those countries where we do have a concern. The concern in the U.S. is of a lower magnitude than in some other countries abrod.

CHAIRMAN PALLADINO: I wouldn't say that so categorically because I think one of the questions we do have in the United States is that of theft. It is possible that some gook go into a reactor and try to take that fuel.

COMMISSIONER GILINSKY: Just for myself, while the agency does accept the current physical protection regulations, including the self-protection rules, I have to say for myself, I don't regard them as adequate.

I hope we are going to hear more -- not today -- but I hope we are going to get more data on the amount of fuel which is irradiated to various levels.

COMMISSIONER ASSELSTINE: Yes.

COMMISSIONER BERNTHAL: I must say on this general subject here, since this is primarily directed at foreign policy objectives, I guess, I hope that someone here today and if not today at a later time, is going to flesh out the foreign policy aspects of this problem. Almost all of this pile of material -- at least as nearly as I can tell, there was very little said about the dimension of the problem.

I realize some of that we probably can't discuss --

COMMISSIONER GILINSKY: Well, in a way it would be useful to hear from an agency like ACDA that is involved directly in dealing with others. I mean, we are of course involved in the licensing of it. We encourage others to switch over.

But in terms of negotiating and talking to others, ACDA, the State Department --

COMMISSIONER ROBERTS: I think that would be quite helpful.

COMMISSIONER BERNTHAL: I mean, I don't even have a good feel here. I am sort of taking it on fiat --

COMMISSIONER GILINSKY: It would be useful.

COMMISSIONER BERNTHAL: -- that, yes, indeed, this is a demonstration of good faith besides our own interests here in discouraging diversion or whatever our domestic interests are.

COMMISSIONER GILINSKY: Yes, there is an important aspect here which I don't want to downplay, of saying, an example, making clear that we believe what we are asking people to do.

Just based on my own experience, I attended a conference on this subject recently which from a technological point of view was kind of pretty postive in the sense that people are pretty optimistic.

But there were expressions from the floor about, you know, people would sort of speak up and say, "What about the United States?" It is pretty clear that people feel strongly that this is something we ought to do together.

CHAIRMAN PALLADINO: Why don't you go ahead?

MR. TURINSKY: The next overhead. I think I will not say more on that one.

(Laughter)

MR. TURINSKY: Let me say, the final; what I am saying here also represents the TRTR university members' views also. Since they are not speaking individually today, I am presenting their views which are parallel with the NEDHO views.

Feasibility considerations, as far as the university is concerned, revolve around not only technical matters which you have heard mainly about so far today, but we have some real concerns about the financial feasibility from our viewpoint. This is a hard time for nuclear engineering programs as it is a hard time for the whole nuclear industry. We are not exactly high on the Dean's funding list for

FEASIBILITY CONSIDERATIONS

TECHNICALLY: PERFORMANCE, DESIGN, MANUFACTURE AND ANALYSIS

FINANCIALLY: ONE TIME AND RECURRING COSTS

LICENSING: SAFETY ANALYSIS AND APPROVAL

COST/BENEFIT EVALUATION CONSIDERATIONS

COSTS:

- FINANCIAL

  ONE TIME

  - FUEL DESIGN, FABRICATION, SHIPPING AND DISPOSAL
  - FACILITY MODIFICATIONS
  - LICENSING

  RECURRING

  - INCREMENTAL O&M
  - INCREMENTAL FUEL CYCLE
- TEACHING, RESEARCH AND SERVICE PERFORMANCE
  - PHYSICS PERFORMANCE
  - AVAILABILITY: DOWNTIME TO CONVERT OR DECOMMISSIONING
  - LICENSING UNCERTAINTY
- PROLIFERATION: FUEL SHIPPING
- SAFETY: ALARA

BENEFITS:

- PROLIFERATION
- PHYSICS PERFORMANCE (MAYBE)
- LEARNING EXPERIENCE
- SECURITY

projects right now, with declining enrollment. Other engineering enrollments, basically, have doubled in the last five years.

We also have a great deal of concern about licensing, the open-endedness of that, and we look at our sister university, at UCLA, and get quite scared about the whole affair of what the cost and the time involved in licensing. We may be very good technically but we do not have the legal resources, et cetera usually, that major utilities or power companies tend to have.

The cost-benefit evaluations we have considered, as you would expect. We are high on the cost listing items and little on the benefits listing items.

We have concerns about one-time cost but also recurring cost. That is, we have some, perhaps, hope that one-time cost we could get some help on. But the recurring cost, it is less clear if there are recurring costs.

CHAIRMAN PALLADINO: Could you give us an example of the recurring cost?

MR. TURINSKY: Well, it is unclear what the recurring costs are for fuel cycle, it is just unclear to our members now exactly what those costs would be, if they would be higher, lower, or what have you. For some of the reactors it may mean more refueling, which would mean more fabrication, more shipment cost.

The teaching, research and service performance, there is concern about the physics performance. Some of our facilities, basically the sort of research we do on them, they are on the range of being marginal. If we lose ten percent, that may mean we are no longer marginal and have to close down the facility.

We are concerned about availability, that is the down time to convert. I think Michigan falls into a group of schools that has a very large nuclear engineering program and they can use a lot of their professors and their students to do the work. There are other institutions that have reactors that basically don't have large nuclear engineering programs and they don't support a solid state physics program. They don't necessarily have those extra type folks -- whether they be students or faculty members -- to fall up, who they call upon as the reactor staff.

If the reactor staff is involved with this activity, they are not involved in supporting, running the reactor and doing the solid state physics, what have you, that they are doing the thermal neutron scanner.

We also have concern on the ultimate loss of availability, which is decommissioning for some of these facilities, particularly if they don't get financial support.

COMMISSIONER GILINSKY: You know, as soon as you mentioned that, let me just repeat what I said earlier briefly

When you talk about ultimate loss of availability, nothing is going to affect you more than if somebody makes off with some of this material from anybody else's reactor.

It seems to me there is a certain element of insurance here for continued availability in this conversion. I think that is something that I don't sense has been taken into account. You know, the kind of problem we would all get into. I mean, the entire research reactor community throughout the world if even a sub-critical quantity where made off with at any one of these plants, we would all have to go into a very, very high level of protection. I just don't know what would happen.

CHAIRMAN PALLADINO: Well, this is why I said I didn't want to dismiss the threat aspect of loss of fuel. I mean, the threat of loss of fuel by people who want to come in and steal it.

COMMISSIONER GILINSKY: You know, you have your benefits which I guess I am anticipating you are going to get to. But there really is a benefit to you, I think, which you might want to think about more.

MR. TURINSKY: It's a probability.

We also have the concern about licensing uncertainty and what that does to the availability of the facility. Proliferation wise there will be, depending on which proposed plan is adopted -- if any is adopted -- increased fuel shipping perhaps will result from this activity, that is on the HEU fuel that would be shipped during the transition period. And then safety, ALARA. Basically, we are going to be shuffling more fuel which will increase the exposure.

The benefits are proliferation, physics performance on some reactors, there may actually be a benefit; the learning experience which was emphasized in the Michigan presentation, that for those universities that do have nuclear engineerings programs it can involve their faculty and students which will be positive. And then perhaps a benefit in security in the sense that with LEU we won't need as high security at these facilities. But that is unclear because of the radiation risk of the fuel.

The next overhead, please.

Now, I listed up here four different scenarios and these are our members' evaluations of the cost-benefit ratio and they are, needless to say, soft but these decisions are hard decisions to quantify since many of the costs and benefits are not really in terms of dollars and cents.

Conversion required as soon as technically feasible with external financial support would have a very high cost. Basically the high cost is the cost of all of the HEU fuel that would not be fully utilized, which is about $15 million.

The conversion required at times of normal reload

Cost Benefit Evaluation:

Scenario	Cost/Benefit Ratio
Conversion Required As Soon as Technically Feasible w/External Financial Support	Very High due to early refueling being required.
Conversion Required At Times of Normal Reload When Technically Feasible w/External Financial Support	High due to incremental "cost" of conversion.
Conversion Required At Times of Normal Reload When Technically Feasible w/o External Financial Support	Very High due to lost teaching, research and service capabilities associated with facilities closin
Conversion Not Required Over Life of Facility But Enhanced Security Required	High due to incremental cost of security and negative impact on teaching, research and service associated w/security. NRC Believes Present Security Adequate. Is Not Effective Abroad To Stop National Diversion.

when technically feasible, with external financial support -- I have dropped the word "very high" to just say "high" -- and its financial costs, candidly, we have some doubt that these numbers of $1-1/4 million, especially when again we look at the UCLA experience where licensing alone is now half a million dollars and they are not done yet.

So, we think the financial cost could be substantially higher, and these other costs, non-financial, the real costs are particularly down-time considerations.

Conversion required at time, during normal reload without external, what that would mean for a number of reactors, candidly, that they would shut down. They do not have the resources to buy new fuel and do all this design change without outside financial help. There, it would be a loss of the teaching, research, and service activities related to those reactors which all of us in this room benefit from.

Finally, conversion not required over life of facility but enhanced security required, there would be, obviously, a high cost associated with enhanced security. Perhaps the more important thing is the negative impact on accessibility of a facility on the university campus; which is important so our students and researchers have open access.

COMMISSIONER GILINSKY: What are the current restrictions on access?

MR. TURINSKY: I cannot address that. I think it varies with the facility.

COMMISSIONER GILINSKY: Are there any restrictions on access to the facility, other than being a student?

CHAIRMAN PALLADINO: Oh, yes.

MR. KELBER: It depends on the plant, I believe. But the reactors I visited as a visitor, I have had to sign in with a recognized escort.

COMMISSIONER GILINSKY: Well, that's on the particular occasion that you visited.

MR. KELBER: I don't know how general that is.

COMMISSIONER GILINSKY: Are there any restrictions on participants in the research program?

(Simultaneous conversation)

MR. SMITH: The current requirement just forced the facility to assure that the student is a bona fide student in good standing, and that any other non-students are known to them and are part of the reactor program.

So, there is no clearance, no background, nothing like that. But we expect the facility to in effect vouch for whoever is in the reactor area.

COMMISSIONER PALLADINO: But not all students have access, or not all the students that are so identified have access directly to the reactor.

MR. SMITH: No, but we do require to have access lists of students that are in there in the off-hours or when the reactor is working. And they have to check that list to make sure that that is a bona fide student.

We have all heard cases of students going to class when they are really not registered.

COMMISSIONER GILINSKY: I know, but is it any more than bing a registered student in the Nuclear Engineering Department?

MR. SMITH: No.

CHAIRMAN PALLADINO: Maybe our place was not typical, but the only people that could be in there unescorted were the ractor operators, the supervisors, and the only other students had to have supervision and escorts as well. They couldn't get in, physically, by key.

I mean, it took a key to get in there.

MR. TURINSKY: It is the same at our facility. Whether that is a regulatory requirement or not, I don't know.

COMMISSIONER BERNTHAL: It is true that if you are a student in Nuclear Engineering you essentially have access to the facility.

MR. TURINSKY: After the appropriate health-physics orientation --

COMMISSIONER BERNTHAL: Yes.

MR. TURINSKY: -- which is mandated by you folks.

All right, the last two points under that is, again -- I guess this is another point of discussion -- is that the NRC presently believes that the security is adequate and at least the agency does, and that this approach would not be effective overseas.

COMMISSIONER GILINSKY: Well, wait a minute. You know, when you say "not effective overseas," if we are going to try and get the enrichment reduced abroad, we are going to have to reduce it here. There certainly is a big benefit to you in having these --

You know, it's one of these situations where everyone would like to keep his current arrangement but he would benefit from everyone else switching over to LEU. It is just something we are all going to have to do together.

CHAIRMAN PALLADINO: Well, he is presenting his arguments.

MR. TURINSKY: The last point was in regard to increased security. If you assume that the source is a problem of national diversion, if the people providing security you can't trust, then you have a unique problem which hopefully does not exist in this country.

The next overhead basically summarizes what I believe is NEDHO's and TRKR's viewpoint, and that is that when we look at the cost-benefit evaluation and we look heavily at the cost, perhaps, we don't see requiring HEU to LEU

KEY RECOMMENDATION:

COST/BENEFIT EVALUATION DOES NOT JUSTIFY REQUIRING HEU TO LEU CORE CONVERSION OR TIGHTER SECURITY.

DOE SHOULD ENCOURAGE HEU TO LEU CORE CONVERSION BY

- DEVELOPING, DEMONSTRATING AND GENERICALLY LICENSING THE NEW HIGH DENSITY FUEL DESIGNS.
- PROVIDING FULL FINANCIAL (ONE TIME AND RECURRING COSTS), TECHNICAL AND LICENSING SUPPORT OF UNIVERSITIES WHO ELECT TO CONVERT.

core conversion or tighter security as being appropriate. What we would recommend, a number of our universities are supportive of conversion and I believe they would convert if the opportunity presented itself technically and financially. That opportunity can present itself with DOE encouraging conversion by, 1) developing, demonstrating and generically licensing the higher density fuels and by, 2) providing the financial, technical, and licensing support to make that all happen.

COMMISSIONER GILINSKY: Well, since I disagreed with some of your points, let me say, I do think it is important that we come up with some government money here.

I also think it is important that this agency do something about simplifying the licensing problems that are involved in the conversion.

MR. TURINSKY: Yes.

CHAIRMAN PALLADINO: I'll join you in that one.

MR. TURINSKY: Let me say, we are skeptical about what you can do to simplify the licensing process.

(Laughter)

COMMISSIONER GILINSKY: I think there are a lot of things we can do if we really sit down and address ourselves to it.

MR. TURINSKY: And we don't know how you write into a rule the fact that if you don't have the money, you don't have to do it, the financial aspects, since it won't come out of this agency.

So, we see a problem with that --

COMMISSIONER GILINSKY: I don't think that would be such a bad use of our own funds, frankly. But I think the more natural place is for it to come from DOE.

CHAIRMAN PALLADINO: We don't have those funds.

MR. TURINSKY; Any other question?

CHAIRMAN PALLADINO: Yes, I had one I guess I should have asked last time. How many of these conversions would have to wait development of new fuel?

MR TURINSKY: That's a better question for Don.

CHAIRMAN PALLADINO: Yes, maybe I should have asked --

MR. KELBER: The question is, how many of the conversions have to wait for the advanced fuel.

CHAIRMAN PALLADINO: I think you gave it, but I don't remember it.

MR. KELBER: Eighteen plus two, right?

MR. TURINSKY: Twenty.

CHAIRMAN PALLADINO: Twenty would have to wait for advanced fuel.

MR. TURINSKY: Wasn't it the 18 low power ones?

MR. KELBER: Fourteen low power, and then --

CHAIRMAN PALLADINO: Why do they need the advanced fuel? I thought it was your high powered ones that need the advanced fuel, that the fuel is not available.

COMMISSIONER GILINSKY: I think to convert without major license modifications. There are two categories. All but two, I think, can do it now with major license modification. At least that was what was --

CHAIRMAN PALLADINO: Again, I guess I need to know what is "major modifications?"

COMMISSIONER GILINSKY: That's a good question.

CHAIRMAN PALLADINO: That does seem key to me. Well, thank you.

MR. TURINSKY: Thank you.

MR. KELBER: The table on lifetime licensing categories is Table 4.1 in Dr. Harris' presentation.

CHAIRMAN PALLADINO: 4.1. Not this one?

MR. KELBER: That's a summary of the table, yes.

CHAIRMAN PALLADINO: Let me find it.

MR. HARRIS: Was the question with a minor license amendment or a major license amendment?

CHAIRMAN PALLADINO: Well, I had a problem. I am trying to say, how many of these reactors have to wait for a new fuel, a fuel that is still under development, and then they said, well, it depends on whether you have a major or minor modification. I had trouble again remembering what "major" and "minor" modifications mean.

MR. HARRIS: The major license revision means that there would be a change to the thermal hydraulics and/or the control for the reactor.

CHAIRMAN PALLADINO: I see. And so that is why I have to wait for new fuel?

MR. HARRIS: Yes. But if you don't wish to draw that distinction -- is that the question?

CHAIRMAN PALLADINO: Yes.

COMMISSIONER GILINSKY: In other words, what you are saying is, if you just want to be able to insert new fuel right where the old fuel went, and just low enriched uranium, you better await the development of better fuel, and that will be a minor change.

If you are willing to --

CHAIRMAN PALLADINO: And that would come about when?

COMMISSIONER GILINSKY: If you are willing to change the specs and so on, you can do it now in all but two of them. But it would involve recalculation, relicensing, and so on.

MR. HARRIS: That's correct.

CHAIRMAN PALLADINO: You would have to wait for how many --

COMMISSIONER GILINSKY: Well, if you are willing to make changes in the configurations, which is what the thermal hydraulics basically means, then you can do it now in all but two of them. But you would have to recalculate, relicense, and so on. That is a major change.

MR. KELBER: For most of the rest the anticipated advanced fuel technology should be available in fiscal '86 or perhaps '87, depending on the schedule of these irradiations. You have to allow for some possibility of slippage. But probably fiscal '86.

CHAIRMAN PALLADINO: Well, I thought that might be important to understand when we address the rule. Okay. Thank you.

Let's see, I guess next --

MR. KELBER: Mr. Kane from DOE. I would like to introduce James Kane from the Department of Energy, Office of Energy Research to express some of their concerns.

CHAIRMAN PALLADINO: Do you have a handout?

MR. KANE: No. There was a letter to Mr. Minogue which was also circulated to the Commissioner's offices back on November 7, summarizing some of that concern.

COMMISSIONER ASSELSTINE: And we have a new one from Shelby Brewer, too, right, that just came in.

MR. KANE: I think you will find that a lot of us are working from the same numbers. So, I don't intend in my presentation to go through a lot of the numbers you have heard. We are using these numbers you have already heard as part of our basis for proceeding.

The first thing, I guess, I would get into is why we are here, why the DOE is involved. I am sure you know this, but let me go through it briefly.

For a long period of time there has been a history of interaction first in the AEC, then in ERDA, finally in the DOE of support for the nuclear enterprise.

We use nuclear reactors in our programs in two ways: Training, which has been mentioned here and also, in the case of the high-powered ones, to do research, where the neutron is often used as a tool for inferring structure in matter. The neutron is often used to synthesize elements, and more and more often to do activation analyses. A reactor is an exceedingly powerful tool for detecting trace elements in many cases.

So, the reactors have a wide usage.

We have two programs that have been going on for a long time, besides the purchase of research. One of these is our fuel provision program where we essentially supply the fuel to the reactors and take -- you noticed a few minutes ago, we do not furnish shipping any more but we take the shipped fuel elements and dispose of them for the universities.

That is the fuel provision program. The other one we are involved in is what you call the reactor sharing program and this is a program where universities that do not have reactors come and use the facilities of universities that do, and again usage is a variety of usages, both for training and occasionally to do research.

So, that is the history.

The use of nuclear reactors cuts across the DOE and I am from the Office of Energy Research which has those two programs I told you about, the provision of fuel and the sharing program.

COMMISSIONER GILINSKY: What is the budget level?

MR. KANE: Several million dollars a year. What is it exactly, about $2 million a year?

VOICE: A million and-a-half.

MR. KANE: One and-a-half million a year for those two things.

In addition to that, there is involvement elsewhere in the Department of Energy. As you probably know, the nuclear energy part of the Department of Energy has responsibility to carry out the technical aspects of the reduced enrichment fuel element development program.

Finally, Defense Programs has responsibility to accept and probably process or store at least the fuel elements after they have been burned up. So, this extends really across the Department of Energy, those three organizational --

CHAIRMAN PALLADINO: Who was the last one?

MR. KANE: Defense Programs, the weapons establishment, which has the capability to reprocess.

CHAIRMAN PALLADINO: And who has the --

MR. KANE: That's Nuclear Energy, the one that Dr. Shelby Brewer, who wrote you the letter, is the head of.

Now, starting with the easy things first, I think without extensive core design -- and by the way, as you certainly know and I will toss this out just as a comment, there are the two commercial reactors that you may hear from today -- well, I guess NBS I should't call commercial. Certainly, Union Carbide is commercial.

In addition to that, we have research reactors that are not licensed but nevertheless, the Department of Energy research reactors which all operate on highly enriched fuel. They are high power 100-megawatt reactors; there is a 60-megawatt reactor, 25 or 35-megawatt reactor and so forth that are used for research purposes. I won't discuss those and talk to them.

Okay, across the top, I think it is the consensus that without major redesign there are two university reactors which under no circumstances -- even if the enrichment, the fuel density corresponding to the silicides, were to be attained, qualified, and shown to be satisfactory. Even then, the fission density within the cores of the MIT and the Columbia-Missouri reactor is such that you would have to redesign to accomodate the fuel. That is my understanding, anyway.

An extensive redesign of this kind would be a very big item for those two reactors, and I will not put any words in their mouths about whether they would be willing to go ahead with it.

CHAIRMAN PALLADINO: What do you mean by complete redesign?

MR. KANE: I just -- no kind of substitution. The fuel density just isn't attainable, even in the silicides, to take -- perhaps to get it derated severely, I think you could without changing the core. You could derate the design by substituting as high as you could get, say, the silicide elements.

COMMISSIONER GILINSKY: What would the derating be?

MR. KANE: I don't know, I really don't.

COMMISSIONER GILINSKY: In proportion to the densities?

MR. KANE: If I said that, I would just be guessing, Commissioner Gilinsky, so I --

CHAIRMAN PALLADINO: Well, we have sort of gone on the assumption that these two are exempted from any rule, and I just wonder whether that's a realistic assumption.

COMMISSIONER GILINSKY: Well, they are different anyway.

MR. KANE: My statement is they are so different that we don't see there is a technical solution to it, is what I am really saying, other than redesign.

COMMISSIONER GILINSKY: But let's see, no technical solution for going down to 20 percent, or no technical solution for going down to lower enrichment?

MR. KANE: No, I think 20 percent. Now, I shouldn't say that so glibly. It may be possible in the combination of complete thermal hydrodynamic design, attaining the silicides and derating slightly, you could get there with it.

COMMISSIONER GILINSKY: It seems to me we have to approch this with a certain amount of common sense and do the best we can.

MR. KANE: Sure.

COMMISSIONER GILINSKY: I would like to see reactors come down as low as -- I would like to see them all come down to 20 percent. But if that is not possible, I think they ought to come down as low as reasonably achievable, or whatever the right words are.

(Laughter)

COMMISSIONER GILINSKY: And I would not dismiss doing anything simply because you can't get down to 20 percent. It would be pretty significant to get it down to 40 percent, or even 60 percent.

MR. KANE: I think technically there is no question, we could do that. You can see the complications it would make if we had reprocessing with several enrichments and so on, complicated but not impossible.

COMMISSIONER GILINSKY: And that may in the end be an interim. You know, some day we may get smarter.

CHAIRMAN PALLADINO: Well, I do think we have to treat them as a special case. But I think we should look at them as a special case after we looked at these others.

MR. KANE: As far as the treatment of these reactors, I concur with what the previous people have said. Let me just go over it briefly.

There are some five plate type reactors of which one, the Michigan one is already under conversion, that we see no technical reasons why in any way you people, in your judgment, wish to proceed. Our recommendation is certainly that you replace as soon as the fuel elements, the low enrichment fuel elements, are qualified and as soon as we made arrangements for closing the back end of the fuel cycle, essentially accepting them back, we see no reason in the case of those five relatively high powered, plate type reactors, why this shouldn't proceed.

CHAIRMAN PALLADINO: You said something there that maybe I didn't catch. You said closing them back in the fuel cycle. You mean you wouldn't be prepared to take this and refuel?

MR. KANE: We have to make sure we are prepared to accept the low enrichment --

CHAIRMAN PALLADINO: What would it take on your part to know that?

MR. KANE: I'm not sure exactly. I don't believe it takes new technology. It may take a modification in process, but I don't think that's an insuperable obstacle. We just have to arrange to do so.

COMMISSIONER GILINSKY: Let's see, reprocessing --

MR. KANE: Yes.

COMMISSIONER GILINSKY: You reprocess the highly enriched stuff. Have you reprocessed any lower enriched material?

CHAIRMAN PALLADINO: Eventually.

MR. KANE: I am sure they have, yes. I don't think there is a technical problem there. Again, it's a --

COMMISSIONER GILINSKY: In my personal view it is a pretty flexible facility.

MR. KANE: The processing tends to be largely chemical, and that, to the first approximation, does not depend on your isotope enrichment, of course. But I am sure if you run one of those plants and have to worry about grids and mixing flows, and have different enrichment --

COMMISSIONER GILINSKY: -- said it was just chemistry.

(Laughter)

CHAIRMAN PALLADINO: Well, if that is a problem, we should understand it, the degree to which it is a problem.

MR. KANE: Yes. I will try to get you a better answer on what this involves, perhaps a written answer is what you would like on that.

Now, from now on, I think what I say -- it will more be a statement of costs and you will have to supply the benefits. I don't really intend to get into a judgment on my part. So, if I tend to harp more severely on costs here, it is because the coin is simpler in costs whereas the coin is more complex in benefits. So, I think that is largely your job, I would give you my opinion if I were asked but I am not going to volunteer on judgments here.

COMMISSIONER ROBERTS: Well, I am going to ask.

(Laughter)

MR. KANE: Let me go through it, then, at the end. Here is how I would proceed in order of doing things if it were my judgment. I would certainly proceed on the plate type reactors as the high enrichment uranium was burned up. In other words, replace the fuel elements as you burn up the existing system. So, that leads to a smooth conversion to the low enrichment fuel.

I would think very seriously before I would go in and change lifetime cores -- that's a judgment.

COMMISSIONER GILINSKY: A judgment on what?

MR. KANE: On the benefits of that.

COMMISSIONER GILINSKY: But what sort of --

MR. KANE: That is one you may not agree with.

COMMISSIONER GILINSKY: I mean, have you looked into the safeguards aspect of it?

MR. KANE: No, no.

COMMISSIONER GILINSKY: Well, but that's the whole benefit.

MR. KANE: All right.

COMMISSIONER GILINSKY: I mean, have you coordinated this with the Defense Program?

MR. KANE: I said that, you know, I wasn't going to try to put it in the coin of benefit. He asked me a specific question and I really -- I think this is your job is to come up with that coin.

COMMISSIONER GILINSKY: It is also DOE's job, certainly in Defense Programs. I wonder whether you have coordinated this with them.

MR. KANE: No, no.

CHAIRMAN PALLADINO: It might be interesting to get their views on that. Not only interesting, but important.

MR. KANE: The safeguards business is a totally different topic and I did not come here prepared to talk about it. It is a topic of great interest to us, as you can imagine.

I guess my reaction to safeguards is, I can probably counter any threat you can hypothesize at cost, and it goes on forever. You have to make a judgment of what threat level you think is one you can live with, and then I think it is relatively straight forward using the tools the DOE safeguards people have developed, particularly Sandia Corporation, to give you what that will cost. Then you can hypothesize a more severe threat and that will cost more. So, that's this game.

If I can help you any further on this, I would be pleased to. But I think you ought to get an expert in safeguards over here rather than me.

CHAIRMAN PALLADINO: But you do bring up a good point. We may want to do that.

MR. KANE: And there has a great deal of technical thought be given to counteracting threats of different levels.

CHAIRMAN PALLADINO: Okay, you want to go on now?

MR. KANE: Okay. I guess a topic that I should bring up is -- and you have been aware of it, you have all mentioned it yourselves so I am just reiterating what you have already said -- that costs due to this -- and I am not talking about the fuel costs, I am talking about the engineering studies, the safety analyses, and those kinds of costs, the licensing.

Anything you can do to make this as gentle as possible is going to probably determine the survivability of some of these reactors. Now, that is not a threat in any sort of a way. But the costs ultimately, in my opinion, will largely have to be borne by the Federal government in some form or other, the costs of this conversion.

It is my opinion in talking to many of the university people that a lot of these operations are hanging by a thread, to use the vernacular, and any sudden lump cost will cause them, the Deans, to reconsider whether that is a continuing endeavor that the department ought to be involved in, the Department of Engineering, Nuclear Engineering.

And I think it will cause the DOE to reconsider how many reactors can we afford to keep going if there are lump costs. So, anything you can do along that line in licensing improvements -- I am not suggesting, I don't know how to do your business in any way -- but the costs is an important thing in this conversion.

Again, I reiterate I am not talking about fuel costs in this case.

COMMISSIONER BERNTHAL: But that does mean that the

DOE would not support -- I don't want to put words in your mouth here. But it seems to me that if this is a desirable objective and if you agree that the reactors that you are now funding, that the research is worthwhile and the educational programs are worthwhile, since this is a desirable objective, somewhat separate from your responsibilities, it seems to me that you would at least be neutral on the question of simply going to Congress and asking for the money to do it.

MR. KANE: There are two questions there. The desirability I don't -- excuse me.

CHAIRMAN PALLADINO: Go ahead.

MR. KANE: Really, I think it is a desirable goal. In fact, I shouldn't say I think it is, it is a desirable goal.

But I think, Fred, you have worked in Congress long enough to know there is no such thing as an increment to your budget that pays for something you do.

(Laughter)

COMMISSIONER ASSELSTINE: It depends upon the program.

(Laughter)

MR. KANE: If the cost of a certain type of research goes up, good research managers analyze and see if they really need that much. I mean, that would be true of a let's say we had a chemistry program that suddenly cost a lot more than it cost in the past. I don't think we would blithely just say, "Hey, it was a good program at a million dollars, it's a good program at two million, we should buy it.

I think you would go back and re-analyze what you are getting for your money and take it on a case-by-case basis.

A final comment, I guess and then, I have not answered your questions very well but I will certainly try.

COMMISSIONER GILINSKY: Let me just say, I think DOE has done a splendid job in developing the technology at Argonne.

MR. KANE: I wish I could take credit for that, but I cannot in any way.

COMMISSIONER GILINSKY: It is a wonderful thing that you have done that.

MR. KANE: Yes.

COMMISSIONER GILINSKY: It would be unfortunate if we would then let the thing drop after having developed these possibilities. You know, it is the one area in this whole larger area of proliferation, what do you do about all these dangerous materials, that really does have a technical solution, at least in large part.

And not to do what we can in this area, I think, would really be a shame, particularly after you have done this tremendous work.

MR. KANE: I will pass your compliments on to Shelby's organization, which is really responsible for this. I would like to take them, but I can't.

I believe that's about -- I will be pleased to respond to any questions I can -- but that's about all I have to say.

CHAIRMAN PALLADINO: Well, my basic question is, how do you see the funding plants for at least the fuel element?

MR. KANE: The fuel element program, as you know, is in our budget in fiscal '84 for $5 million. We requested a similar amount for the next fiscal year. You also know I can't discuss the details of our budget. As far as I know -- I don't know of anything that has happened to that request.

I would suggest you follow up on that as soon as the President's budget -- I will be glad to let you know.

CHAIRMAN PALLADINO: Well, that is something we will want to follow up.

MR. KANE: Yes.

CHAIRMAN PALLADINO: At least it is in the '84 budget.

MR. KANE: We put it in the departmental budget.

COMMISSIONER ASSELSTINE: At five million?

MR. KANE: Yes.

CHAIRMAN PALLADINO: Okay, so we will have to watch carefully that that is not lost. But we also have to make sure that it is going to be used properly.

COMMISSIONER GILINSKY: But let's see, the numbers were put up for converting the entire batch, and you ran up to something less than $15 million.

MR. KANE: Oh, yes.

COMMISSIONER ASSELSTINE: That's right.

MR. KANE: This doesn't include that kind. This is just more R&D on the technical aspects.

CHAIRMAN PALLADINO: Oh, no, I was thinking about the money to help the universities make their conversion.

MR. KANE: There is none of that in our budget for '85.

CHAIRMAN PALLADINO: Oh.

MR. KANE: There is no request in fiscal year '85 for reactor conversion, excuse me.

CHAIRMAN PALLADINO: That's the bottom line I was looking for.

COMMISSIONER GILINSKY: Let me just go back to those numbers. The $15 million is over something more than a five-year period, presumably.

MR. KELBER: Four to five years at least.

CHAIRMAN PALLADINO: Was that the fuel cost?

COMMISSIONER GILINSKY; No, that was the entire conversion cost, at least as estimated in the report.

COMMISSIONER ASSELSTINE: Yes, that's right.

COMMISSIONER GILINSKY: And that would take place over somewhere between a four to ten-year period, let us say.

So, you are dividing it at least by five. So, we are talking about three million dollars a year for, say, five years.

CHAIRMAN PALLADINO: But what I am worried about is if we came out with a rule that says, "Thou shalt convert" and we don't say there is no money from DOE --

COMMISSIONER GILINSKY: Well, I think we have to overrule them, we have to have money.

(Laughter)

CHAIRMAN PALLADINO: What if we say, "Convert but get your money from DOE?" They would come to you and what would you do, just say, "Well, we don't have the money?"

MR. KANE: Well, in fiscal '85, since we didn't ask for any, you know, we have a "chicken and egg" problem here. I don't think the OMB would have taken too kindly for our request and you people have not published your rule yet. We have no legal authority to replace fuel. I guess we could. I would be surprised if that survived OMB's scrutiny.

Once you have issued it and then it is a requirement, I think there is every chance we can go for it in the budget with a budget request.

CHAIRMAN PALLADINO: Well, the problem -- I don't want us see the universities or the other owners put in the middle where we say, "Convert," and they say, "Okay, we'll go to DOE for the money" and they say, "We have no money."

We are going to have to work together to get something that will be feasible.

COMMISSIONER GILINSKY: Well, any rule would come out as a proposed rule. So, there would be some period during which to try to bring all this into harmony.

COMMISSIONER ASSELSTINE: Yes.

MR. KANE: Okay.

COMMISSIONER ASSELSTINE: But I think Commissioner Gilinsky's point is a good one, that when you are looking at an annualized basis, the cost even of a fairly extensive conversion program would still be only about 60 percent of what your current budget is on the research side.

COMMISSIONER GILINSKY: Now, do you expect that fuel development program to continue for some time, or is much of that work completed so that --

MR. KANE: No, I think it has several years to go. Again, Mr. Mastern in the audience, if you have specific questions he could answer them; I can't.

COMMISSIONER GILINSKY: Well, it is important to develop those too.

COMMISSIONER ASSELSTINE: Yes.

MR. KELBER: I believe, Commissioner, that the final date anticipated now is 1990 for the very high density silicides. But I learned from experience not to forecast research accomplishments --

COMMISSIONER GILINSKY: You know, I made this point earlier but let me just harp on it once again.

If somebody makes off with some fuel anywhere, we are going to go into a security exercise that is going to make $15 million just look like peanuts.

(Laughter)

COMMISSIONER GILINSKY: And that is going to apply not just to the licensed reactors, it is going to apply to your reactors. It is going to apply to every damned thing.

I think that this is not something we want to "nickel and dime," this is just a sensible thing to do. Now, the rate at which we do it, who comes first and so on, is something we need to work out in some reasonable way.

MR. KANE: You know, I was hoping -- I couldn't come up with anything very constructive today. But if you do tabulate it by a kind of a cost-benefit where the benefit is getting a kilogram out of circulation, it is obvious where you start, those are the ones we all discussed today, and then the amount you get out per dollar invested drops down. You will have to decide where the tail is that you cut off and say, "It's no longer a significant risk to leave that somewhere." That is a decision -- you see, we have them all the way down -- we have a one watt reactor. all the way up to ten megawatts, that I am talking about today I do not know the fuel loading in some of those little ones, but it is very small.

Whether you consider that trivial or not is a judgment you will have to come to because it will cost you more per gram of U 235 sequestered as you get down to those little reactors because the fixed costs look kind of comparable for them all. We have assumed they are comparable, that may be a wrong assumption.

CHAIRMAN PALLADINO: I wanted to ask you, in addition to the fuel, would DOE consider setting up some fund to help other aspects of the conversion?

MR. KANE: I said a few minutes ago that my judgment of the nuclear reactor universities' business is such that unless the DOE or someone else that has a programmatic interest in those reactors does set up a fund, most of them will not survive. That sounds like a dramatic statement, but it is a true statement.

CHAIRMAN PALLADINO: Well, that is why I am asking you. I would like to see a fund set up that not only covers the fuel but to which universities might have access to help in getting other parts of a structure changed if need be

MR. KANE: Yes. I think that is not unreasonable. I am being careful to say, we won't guarantee the survival of them all. I am very careful to say that.

CHAIRMAN PALLADINO: Okay, any other questions? Well, thank you very much.

MR. KANE: Thank you.

COMMISSIONER GILINSKY: Thank you very much.

CHAIRMAN PALLADINO: Go ahead.

MR. KELBER: I would like to not introduce to you Dr. Robert Carter from National Bureau of Standards. This is one of the two large reactors that we did not consider. It is in the detailed study.

CHAIRMAN PALLADINO: You did not consider it in the study?

MR. KELBER: Not explicitely. It is not a university reactor. Many of the comments apply. There are some additional considerations that apply to these.

MR. CARTER: I want to address the impact of LEU on high performance research reactors, not just the Bureau of Standard's reactor. And the high performance research reactors are those that have made great efforts to optimize the neutron flux through operating efficiency and experimental facilities to enable them to support frontier research.

In this country I would include several of the DOE reactors, the National Bureau of Standards reactor, and the research reactors at MIT and the University of Missouri as high-performance reactors.

A need for such reactors is illustrated in the first viewgraph which shows a few of their many applications. It is far from all inclusive.

New industrial technologies are using neutrons more and more as a tool to understand the processing of important new materials such as -- identified metals and fast ionic conductors, and the use of neutron methods is growing rapidly in the study of the catalysis and biotechnology.

I might mention before I make my next statement that the National Bureau of Standards is in the Department of Commerce which is, of course, quite concerned with the U.S. position in international trade and technical competition.

I have heard it said that U.S. reactors should use LEU in order not to compete unfairly with research reactors overseas that are being asked by our government to do the same. I want to point out that we are well behind our European counterparts. Their effort is three times as large as ours. They have recently built new research

12/19/83

NEED FOR HIGH PERFORMANCE RESEARCH REACTOR

APPLICATIONS

- PROPERTIES OF RAPIDLY SOLIDIFIED METALS
- NONDESTRUCTIVE EVALUATION BY NEUTRON SCATTERING
- HIGH TECHNOLOGY MATERIALS (I.E., FAST IONIC-CONDUCTORS)
- BIOTECHNOLOGY
- CATALYSIS
- RADIOISOTOPES

U. S. POSITION VS. EUROPE

- U. S. EFFORT 1/3 OF EUROPE'S
- EUROPE BUILDING NEW REACTORS/U.S. DEAD IN THE WATER
- U. S. SCIENTISTS USE EUROPEAN FACILITIES, BUT ACCESS IS VERY LIMITED

CONCLUSION:

U. S. MUST MAXIMIZE EFFECTIVENESS OF EXISTING FACILITIES reactors whereas we have not built a new high performance research reactor in twenty years and are not likely to do so in the near future.

Therefore, the U.S. must make the most of its existing facilities.

May I have the next viewgraph? I'm sorry. Yes, that's it.

I want to address high performance reactors and LEU. I am using the NBS reactor as an example because I am more familiar with it, but most of what I say would apply to any of the other reactors. I might mention that the NBS reactor currently operates at 10 megawatts and we hope shortly to be operating at 20 sometime this year.

We made a great effort to optimize the neutron flux versus power, to tailor our neutron spectrum to the needs of neutron scattering research. To improve the signal to noise ratio. To make the most of our fuel utilization, and to achieve the maximum on-line operating time.

To do this has taken considerable effort and we have gone to a lot of expense. We are using heavy water moderator to minimize the neutron absorption, thereby giving us the maximum number of neutrons per power, and if you add LEU to that, you are going to put in a lot more absorbing material and to some extent negate the considerable

HIGH PERFORMANCE RESEARCH REACTORS AND LEU
(NBS EXAMPLE)

- GREAT EFFORT MADE TO OPTIMIZE:
  - NEUTRON FLUX VS. POWER
  - NEUTRON SPECTRUM
  - SIGNAL TO NOISE
  - FUEL UTILIZATION
  - ON-LINE TIME

- OPTIMIZATION ACHIEVED IN NBSR BY:
  - USE OF D_2O MODERATOR
  - SPLIT CORE
  - HEAVY FUEL LOADING (1.2 G/CM^3 U-235)
  - EXTENSIVE BURNUP (63% AVERAGE)
  - OPERATE AT MAXIMUM POWER

- PROBLEMS WITH LEU
  - LOWERS THERMAL NEUTRON FLUX
  - INCREASES BACKGROUND
  - EXTREME LOADING WITH SILICIDE FUEL REQUIRED
  - SUCH LOADING LEAVES LITTLE MATRIX--IMPLIES POOR FISSION PRODUCT RETENTION
  - QUESTIONS ABOUT BURNUP LIMIT
  - TRANSITION FROM YEARS OF EXPERIENCE TO RELATIVELY UNTESTED FUELS

NBS Submission

effort we have gone to in using D_2O moderator. Our core is designed with a split core. I won't say any details about it, but it minimizes the fast neutrons to get into our beam tubes.

We have a heavy fuel loading, 1.2 grams per cubic centimeter. We have extensive burnup, we achieve extensive burnup, averaging about 63 percent, and we operate at the maximum power we can, consistent with the cooling capacity that we have.

Now, in this context some of the problems with LEU are that it lowers the thermal neutron flux and we have gone to great trouble to try to maximize that.

COMMISSIONER BERNTHAL: Just for curiosity, what is your maximum flux?

MR. CARTER: Our maximum flux will be around 20 megawatts which we hope to get shortly. It will be around four times ten to the 13. But there is more than just the neutron flux itself -- four times ten to the 14, I am sorry.

There is more than just that. There is the size of the beam tubes. There is the quality of the beam, how much fast neutrons are there that you have to maybe filter out or shield against. There are a lot of things that go into it, all of which we have tried to optimize.

In any case, this LEU would lower the thermal neutron --

COMMISSIONER GILINSKY: When you say LEU, you are talking about 20 percent material?

MR. CARTER: Forty percent would certainly go about half as far towards that. It would also lower but not as much, perhaps.

COMMISSIONER BERNTHAL: How much, though, if not as much. Do you have any idea? We asked this question two or three times.

MR. CARTER: I would say in the case of our reactor, I have not made detailed calculations. It would be quite complex for the heavy water reactor. But I would say it would be a 10 to 15 percent decrease in the thermal neutron flux and the fast neutron background would probably go up five or ten percent, which gives you -- hurts your signal-noise ratio.

COMMISSIONER BERNTHAL: I am surprised. I think we had a comment earlier today that ten percent somehow in a marginal experiment wipes out the experiment. And I am afraid I don't quite understand that. Now, the fast flux background, I understand better. But I don't quite understand how ten percent --

MR. CARTER: I didn't make the statement that it wipes it out. But on the other hand it is important -- you go to a great deal of effort to try to get an extra ten percent as I have illustrated here.

Perhaps another way of looking at it is, if you look at just the neutron scattering research that is done in this country, perhaps $6 million a year at our reactor, maybe around $20 million, maybe, throughout the total high performance reactors.

Now, if you just lower the output of that by ten percent, you are talking $2 million a year unused investment and research, which is a non-trivial amount. But you also are going to lose certain -- not all but certain -- marginal experiments. So, you are really pushing to achieve.

COMMISSIONER BERNTHAL: Nobody, I think, probably is more sensitive to how little the research worker likes to lower his accounting rate by a factor of two. But finally, if you lower your flux ten percent, unless I am misunderstanding the kind of work that you are doing, basically you are counting events, and the lowering of the statistics is --

MR. CARTER: Well, there are several things that are involved in there. First of all, I was speaking of 10 to 15 percent.

There are experiments that you have trouble maintaining the experimental conditions for a finding, finite length of time. You have examples of it, the liquid helium temperature that you are pumping and you are trying to maintain a very accurate temperature. These are very difficult to push, and ten percent is not going to necessarily make or break them, but it sure does make some difference in how those experiments can be performed and, as you increase the neutron background too, you are hurting your signal-to-noise ratio.

COMMISSIONER BERNTHAL: Well, that's a reasonable --

MR. CARTER: There is a combination. I am not trying to say that 15 percent will kill you. But I am saying that in designing these reactors a great deal of effort has been put into trying to get every last bit, including a 10 or 15-percent effect.

Now, the other thing is that we require our heavy fuel loading, which would probably go up if you went to low enriched fuel, would require the extreme loading that a silicide fuel might provide, possibly not as low as 20, but you would have to go with these newer -- really, the newest fuels and that --

And one of the problems is, you have to use about as heavy a loading as you can get with that. When you do this, you have less aluminum matrix around the silicide particles with the distinct possibility that should you have a cladding failure, you may have a greater release of the fission product from the fuel.

CHAIRMAN PALLADINO: Are you in the same boat as MIT and the University of Missouri were describing?

MR. CARTER: We are higher power and our programs are quite different. Our loadings are not quite so high as theirs are, but are close to it.

CHAIRMAN PALLADINO: In other words, even if they developed a new fuel --

MR. CARTER: With that loading, and assuming that you have to go up somewhat in loading, I think the seven grams per cc that they talk about might just -- might just make it.

CHAIRMAN PALLADINO: I see.

MR. CARTER: But then, another thing is -- and in the operating cost it is very important to achieve as much burnup as you can in your fuel. As you see, we have achieved a great deal of burnup. There is some question about how far you can push the new fuels, and of course this is being looked into. But these are questions that are not answered at this time.

And then, we are being asked to go from fuels that have many, many years of safe operating experience to a relatively untested fuel and reactors that are pushing themselves as far as consistent with safety.

The next viewgraph, please.

Now I want to be a little parochial and speak of the NBS reactor itself.

COMMISSIONER GILINSKY: (Inaudible)

NBS-DOE LINK

CONTENTION:

NBS SHOULD BE TREATED NO DIFFERENTLY THAN DOE RELATIVE TO LEU REQUIREMENTS

WHY?

- BOTH ARE FEDERAL AGENCIES
- NBS IS A MAJOR FEDERAL LAB AS ARE THE DOE LABS
- THE NBSR ALSO IS A NATIONAL RESEARCH REACTOR CENTER WITH AT LEAST 5 INSTRUMENTS AS GOOD OR BETTER THAN ANY IN U. S.
- FUEL PROCUREMENT IS THROUGH INTERAGENCY AGREEMENT WITH DOE MAKING NBS AN INTEGRAL PART OF THE DOE FUEL PRODUCTION LINE
- TERMINATION OF THIS ARRANGEMENT NECESSITATED BY THE USE OF LEU WOULD RESULT IN SIGNIFICANT INCREASE IN FUEL COSTS FOR NBS

NBS Submission

MR. CARTER: What I said was typical of other reactors and I didn't mean it to apply only to us.

But I suggest that NBS should be treated no differently than DOE relative to LEU requirements. Why? Both are Federal agencies. NBS is a major Federal lab, as are the DOE labs.

The NBSR also is a national research center with at least five instruments as good or better than any in the U.S. Fuel procurement is through interagency agreement with DOE, making NBS an integral part of the DOE fuel production line.

Termination of this arrangement with DOE would significantly increase the costs to NBS of fuel procurement.

CHAIRMAN PALLADINO: Do you follow NRC's security requirements, or do you follow --

MR. CARTER: Yes.

(Simultaneous conversations)

CHAIRMAN PALLADINO: Well, are DOE's security requirements tougher than ours?

MR. CARTER: I can't really speak to that, I'm not --

CHAIRMAN PALLADINO: What I am saying is, if you are a DOE lab, do you have the protection that goes along with the DOE lab?

COMMISSIONER ASSELSTINE: No.

MR. CARTER: I can't say just what all the DOE's are. As a Federal laboratory we do have our own police force and this type of thing.

May I have the final viewgraph?

This is just in summary. High performance reactors are important to U.S. technology. Effectiveness of U.S. facilities should be maximized. The use of LEU would be detrimental to the performance of these reactors.

There remain many unanswered questions about the safety and economics of LEU when used in reactors that are already being pushed to the power and fuel utilization limits.

And parochially again, the NBS reactor is a national resource and should not be treated differently from other national lab reactors.

CHAIRMAN PALLADINO: Okay, thank you. Any other questions?

COMMISSIONER ASSELSTINE: No.

CHAIRMAN PALLADINO: Well, we appreciate your joining us.

MR. KELBER: The last statement on our list is Mr. McGovern from Union Carbide and again, they have an industrial facility with a program unique to its own purposes.

MR. McGOVERN: Good afternoon, gentlemen.

CONCLUSIONS

- HIGH PERFORMANCE REACTORS ARE IMPORTANT TO U. S. TECHNOLOGY.
- EFFECTIVENESS OF U. S. FACILITIES MUST BE MAXIMIZED.
- THE USE OF LEU WOULD BE DETRIMENTAL TO THE PERFORMANCE OF THESE REACTORS.
- THERE REMAIN MANY UNANSWERED QUESTIONS ABOUT THE SAFETY AND ECONOMICS OF LEU WHEN USED IN REACTORS THAT ARE ALREADY BEING PUSHED TO THEIR POWER AND FUEL UTILIZATION LIMITS.
- THE NBS REACTOR IS A NATIONAL RESOURCE AND SHOULD NOT BE TREATED DIFFERENTLY FROM OTHER NATIONAL LAB REACTORS.

NBS Submission

My purpose here today is to describe the reactor facility to you, to tell you something about what we do with it, and try to assess as far as what we know right now what will the impact be on our operation if we were required to shift to low enriched uranium.

The Tuxedo reactor is operated by Union Carbide, it's five megawatts. It is a research reactor in nature. However, the function is primarily to produce radio chemicals and radio pharmaceuticals, and to do neutron service radiation work.

The principal products are the isotopes of Mo-99, Xe-133, I-131, I-125. We do make molybdenum technetium generators and technetium diagnostic reagent kits for nuclear medicine.

We also do quite a bit of NTD silicon radiation work.

The next slide, please.

A profile of the industry in which this facility participates in. First of all I would like to say, it is a commercial venture and we operate to make a profit.

The essence of the industry is that we supply short-lived radio isotopes and this requires a continuous operation. The isotopes that we produce have half-lives of days, therefore we have to operate week-in and week-out.

The major isotope is molybdenum 99. It represents about 80 percent of the total isotopes in terms of curies

UNION CARBIDE NUCLEAR REACTOR
Tuxedo, N.Y.

Research Reactor

- 5 Mw Power
- Light Water Moderated & Cooled
- ~ 95% Duty Cycle
- Uranium-Aluminum Fuel (93% U-235)

Hot Laboratory

- 5 Major Hot Cells
- 50,000 Ci Elements Z, 3-83
- ~ 60% Duty Cycle

Function

- Produce Radiochemicals
- Produce Radiopharmaceuticals
- Neutron Service Irradiations

Products

- Mo-99, Xe-133, I-131, I-125, etc.
- Mo-99/Tc-99m Generators, Tc Diagnostic Reagent Kits
- NTD Si, etc.

REACTOR BASED
RADIOCHEMICAL PRODUCERS
WORLD MARKET

The Sterling Forest Laboratory in Tuxedo is a commercial venture which operates for profit.

Reliable supply of shortlived radioisotopes is the essence of the industry. One in every four patients in U.S. hospitals benefits from a nuclear diagnostic procedure. 70 percent of all nuclear diagnostic procedures are performed with the Tc-99m isotope, the daughter of Mo-99.

Product Mix:

Mo-99 (Fission Process)	80%
Xe-133	5%
I-131	5%
I-125	5%
Others	5%

The isotopes of Mo-99, Xe-133 and I-131 are separated from the fission products of U-235.

Producers (F.P. Mo-99):

Union Carbide Corporation (UCC)	45%
Atomic Energy of Canada Ltd. (AECL)	45%
I.R.E. Belgium (IRE)	5%
Australian Atomic Energy Commission (AAEC)	5%

AECL, IRE, and AAEC are government subsidized enterprises.

that are used in nuclear medicine.

Some statistics. One in every four patients that is admitted to a United States hospital today is tested by some nuclear diagnostic technique.

The producers of these isotopes, major producers of these isotopes, are ourselves, Union Carbide, the Atomic Energy of Canada, Ltd., I.R.E. in Belgium, and the Australian Atomic Energy Commission.

I would like to point out that the last three on that list are highly subsidized government facilities.

The next slide, please.

This is just to give you some idea of the impact that our facility has on the public health in the United States. The top list of studies, or diagnostic techniques, are generally called in vivo tests and there are about five million of these performed in the United States every year. The tests that are facilitated from the isotopes that come from Tuxedo are about half that, or two and-a-half million.

The bottom list are the in vitro procedures or the major in vitro procedures, there are many more. There are 120 million of those performed every year, and about 60 million are facilitated by the isotopes that come from Tuxedo.

Next slide, please.

UNION CARBIDE, NUCLEAR PRODUCTS
IMPACT ON PUBLIC HEALTH

NUCLEAR MEDICINE (IN VIVO TESTS)

TYPE OF TEST	TOTAL 1980 TEST PROCEDURES	% UCC CONTRIBUTES
LUNG INHALATION	320,000	30%
LIVER	1,425,000	50%
BONE HMDP	1,615,000	50%
BLOOD POOL	100,000	50%
KIDNEY	456,000	50%
LUNG PERFUSION	775,000	50%
BRAIN/THYROID	500,000	50%
TOTAL	5,181,000	2,500,000

RADIOIMMUNOASSAY (IN VITRO TESTS)

THYROID HORMONES	48,000,000	50%
DIGOXIN	14,000,000	50%
HUMAN CHORIONIC GONADOTROPIN	11,000,000	50%
B-12/FOLATE	6,000,000	50%
I GE IMMUNE TEST	6,000,000	50%
CORTISOL	4,000,000	50%
ESTRIOL	4,000,000	50%
ANGIOTENSIN	1,500,000	50%
DIGITOXIN	1,400,000	50%
METHOTREXATE	120,000	50%
OTHERS	25,000,000	50%
TOTAL	~ 120,000,000	60,000,000

There are two general categories of considerations, technical considerations, that we looked at when we were asked to assess the impact of converting to LEU in our facility.

The first, of course, is operating safety. You have heard a lot about today, talk about cladding integrity and safety during normal service of the fuel, and also under accident conditions.

I would just like to make a general statement there that Bob Carter hit upon, that the high-enriched fuels with failure low-loading densities have been used for the past 30 years. It is a very good history with them, they have been very well qualified -- very well qualified for a normal service and for the accident conditions where a lot of data was generated in the Spurt and Borax tests many, many years ago.

I am not sure you can model accident conditions with computer codes, I am sure there might be people here who would disagree with that. But I think it ought to be considered what would happen to these high-density fuels in accident conditions as well as operating under normal service.

The other technical consideration as far as operating safety with regard to our facility would be the thermal hydraulic behavior, and we would want to maintain the

LEU CONVERSION

TECHNICAL CONSIDERATIONS

OPERATING SAFETY:

CLADDING INTEGRITY

(A) NORMAL SERVICE

(B) ACCIDENT CONDITIONS

THE LOW DENSITY, HIGH ENRICHED FUELS HAVE BEEN PROVEN TO BE RELIABLE IN NORMAL SERVICE AND UNDER ACCIDENT CONDITIONS. THEY HAVE PROVEN RELIABLE IN APPROXIMATELY 30 YEARS OF NORMAL OPERATION AND ALSO UNDER ACCIDENT CONDITIONS DEMONSTRATED IN THE SPERT AND BORAX TESTS.

PERFORMANCE OF THE HIGH DENSITY, LOW ENRICHED FUELS CAN BE MODELED FAIRLY WELL IN COMPUTER CODES HOWEVER BEHAVIOR UNDER ACCIDENT CONDITIONS MAY NOT BE AS PREDICTABLE WITHOUT SOME EMPIRICAL DATA.

THERMAL HYDRAULIC BEHAVIOR

(A) HEAT FLUX

(B) COOLANT CHANNEL DIMENSIONS

IT IS IMPORTANT TO MAINTAIN THE SAME THERMAL HYDRAULIC BEHAVIOR TO AVOID MAJOR COOLING SYSTEM CHANGES.

OPERATING EFFICACY:

NEUTRON ENERGY SPECTRUM

THERMAL NEUTRON FLUX LEVEL

THE UCNR OPERATES PRIMARILY FOR PRODUCING RADIOISOTOPES AND PERFORMING SERVICE IRRADIATIONS COMMERCIALLY. THE FORD REACTOR CONVERSION TO LEU RESULTED IN A HARDENED NEUTRON FLUX SPECTRUM AND A REDUCTION IN THE THERMAL NEUTRON FLUX. THESE CHANGES WILL HAVE SERIOUS CONSEQUENCES IN THE UCNR OPERATION.

same behavior or the same characteristics thermally and hydraulically because if you diverted from that you would get into major facility modification expenses. It would be a capital investment. Extra cooling or changes in the cooling system would be the primary investment required.

Also, similar hydraulics behavior, we believe, is important to maintain because it would tend to give you the same neutron spectrum in the core, if you had the same metal to water ratio.

CHAIRMAN PALLADINO: Could you get by with the seven grams per cc?

MR. McGOVERN: Yes, we get by with less than that, yes, sir.

The operating efficacy is another technical consideration. The major function of this facility is to produce isotopes. And the absolute thermal neutron flux level is very important when you want to produce isotopes, and you also want to maintain your neutron energy spectrum because if you change the spectrum, you change the results of your targets.

The licensing consideration, I think everybody has spoken to that. And our assessment is the same. It would take many years, several years. to convert wholly from high enriched uranium to low enriched uranium.

CHAIRMAN PALLADINO: How much would your cost be,

LICENSING

REVISE TECHNICAL SPECIFICATIONS:

(AT LEAST 2 MAN YEARS UCC & NRC)

REVISE SAR:

(RENEWAL OF PRESENT LICENSE
STARTED 1980 AND RENEWAL IS
EXPECTED IN 1984.)

MAJOR LICENSE CHANGE:

(PUBLIC HEARING AND EIA)

WE AGREE WITH THE CONCERNS OF THE UNIVERSITY REACTOR COMMUNITY ABOUT THE SUBSTANTIAL EXPENSE INVOLVED IN THE REQUIRED LICENSE RENEWAL PROCESS THAT WILL BE REQUIRED IN LEU CONVERSION.

IMPLEMENTATION

ROUTINE OPERATION MUST NOT BE INTERRUPTED.

WILL NEED U_3Si_2 FUEL WITH HIGH LOADING DENSITY (1986).

LICENSE 1988

INSTALL INCREMENTALLY 1989 - 1990.

are you going to cover that?

MR. McGOVERN: I'll cover that in the next couple of slides.

CHAIRMAN PALLADINO: Okay.

MR. McGOVERN: The implementation of conversion we see taking place like this: We must maintain continuous operation because of the nature of the business that we are in. So, we would have to change over incrementally. We could not take a high enriched core out and put a low enriched core into place.

We would need to use the silicide fuel which is the higher density fuels for that. They have not quite been developed yet or approved. They have been developed, they have not been proven yet. In fact, they are probably not going to be ready for routine use until sometime late 1986.

We would probably not be able to get a license until 1988 at the earliest. That is two years after the fuel becomes available, and it would probably take us a year to change over from the low enriched to high enriched full core.

So, we are talking 1990, if we started today.

The financial considerations are another matter. The cost of conversion would take the form of the relicensing cost, many man-years of relicensing effort here.

The initial fabrication cost. The latest estimate

LEU CONVERSION

FINANCIAL CONSIDERATIONS

COST OF REACTOR CONVERSION:

RELICENSING COST

INITIAL FABRICATION COST (U_O, ALUMINIDE, SILICIDE)
CURRENTLY ESTIMATED TO INCREASE 15 PERCENT

INSTALLATION COST

FUEL LIFE (PERCENT BURN-UP)

REPROCESSING COST

IF REQUIRED TO DO SO, IT WILL BE DESIRABLE TO CHOOSE AN LEU THAT WILL MAINTAIN FLUX LEVELS AND ENERGY SPECTRUM AND ALSO YIELD OPERATING ECONOMICS THAT WILL COMPENSATE FOR THE CONVERSION EXPENSE. SOME BASIC LEU FUEL DESIGNS ARE PRESENTED IN THE FOLLOWING TABLE.

LEU FUEL LOADINGS
(GMS U-235)

		DESIGN NUMBER AND # OF PLATES & MEAT WIDTH (MM)				
TYPE	U DENSITY GM/CM^3	1 16/.51	2 18/.51	3 17/.76	4 16/1.0	
U_3O_8 OR U_3Si_2	2.3	-	-	222	276	> CURRENT COST
U_3O_8 OR U_3Si_2	3.2	196	220	310	383	↑
U_3Si_2	4.0	244	275	387	479	↓
U_3Si_2	4.8	293	330	464	575	≤ CURRENT COST
U_3Si_2	6.0	367	412	580	719	
		← METAL/H_2O	→	→ >	METAL/H_2O	

THE FUEL DESIGNS APPEARING IN THE LOWER LEFT QUADRANT MAY BE SUITABLE TO PROVIDE THE NEUTRON SPECTRUM AND OPERATING ECONOMY THAT IS IN THE UCNR TO MAINTAIN OPERATING CONTINUITY.

COST OF ISOTOPE PRODUCTION:

REDUCED THERMAL FLUX WILL INCREASE VARIABLE OPERATING COST PROPORTIONATELY. (IF VARIABLE COST OF ISOTOPE PRODUCTION IS SEVERAL MILLION DOLLARS THEN A 10 PERCENT REDUCTION IN, THERMAL NEUTRON FLUX WILL CAUSE INCREASED OPERATING EXPENSE OF SEVERAL HUNDRED THOUSAND DOLLARS.

HARDENED FLUX WILL INCREASE TRANSURANIC PRODUCTION IN ISOTOPE TARGET WASTE. (THIS WILL ADD A SUBSTANTIAL COST IN WASTE DISPOSAL. IT MAY PRECLUDE OUR USING COMMERCIAL LLW BURIAL SITES.)

HARDENED FLUX WILL INCREASE FAST NEUTRON DAMAGE IN NTD SI.

by the fabricator -- the only fabricator in the United States -- says that it would cost about 15 percent more. That is his estimate today. Who knows what it will be two years from now when these fuels are finally proven out.

The installation cost, I don't think that would be very much more than just changing fuel and doing some calibration tests, perhaps some instrumentation changes. I don't really know. I'll have to talk to Bob Burn about that.

Fuel life would have a bearing on the fuel loading, the uranium loading in the fuel assemblies. And we would want to pick a fuel that would give us the economies of operation to overcome some of the initial costs of changing over. So, you would want to get a better performing fuel. That would dictate what kind of fuel we chose.

Then there is the reprocessing cost to consider. We don't know what that is or will be for the low enriched fuels. DOE has not figured that out yet.

The chart that I put there is a presentation of some of the basic designs that have been suggested by the A&L people, the objective being for us to maintain the same quality of neutrons that we have in the core in terms of absolute level and in terms of energy spectrum, and also to try to preserve the economies of operation.

When you take those two primary considerations into account, we are kind of stuck in the lower left-hand corner of that chart where we would want to have fuel loadings or densities of above 4.5 grams per cc. So, ew are limited to the silicide fuels if we want to maintain a certain consistency of operating cost.

CHAIRMAN PALLADINO: What do the design numbers mean, the 4/12?

MR. McGOVERN: I'm sorry, that is not too well explained. The design numbers -- the numbers are just arbitrary, design No. 1, 2, 3 and 4. The 16/51 indicates 16 fuel plates per hour and .51 is the thickness of the meat, of the fueled section of the pipe.

CHAIRMAN PALLADINO: And what are the numbers below that, then?

MR. McGOVERN: The numbers below are the grams of u-235 per element.

CHAIRMAN PALLADINO: I see.

MR. McGOVERN: The second column I should correct, and I should have corrected it first off. That is not PU, that is supposed to be density of uranium in terms of grams per cubic centimeter.

COMMISSIONER GILINSKY: Mr. McGovern, I apologize, I am going to have to leave. But I do want to say, I will examine the rest of the transcript so I can follow your presentation, and that also applies to Mr. Leventhal.

Thank you.

MR. McGOVERN: I'm sorry you have to go.

(Commissioner Gilinsky leaves hearing room.)

MR. McGOVERN: The other cost consideration we cannot ignore is the cost of the isotope production. Because you know, I think the Michigan reactor has experienced a reduction in the absolute level of thermal neutrons.

If that is the case, then the incremental cost of your production, of your isotope production, changes inversely proportional to your flux level.

And if your incremental operating cost is a few million dollars and if your flux is reduced by ten percent, then your cost goes up by a few hundred thousand dollars, or several hundred thousand dollars. These numbers are not very well known right now. Perhaps they can be predicted but you never really know until you put it in the core and you put your targets in, and you find out what you get out of the separation process.

The hardened flux will produce a higher degree of transuranic material in our waste. I did not mention this before, but the isotopes that we produce are produced from the fission products of uranium. We irradiate uranium to fission the uranium and then we chemically separate the desirable isotopes from the fission products. And using uranium as the target material, the harder your neutron flux is in the core, the higher your plutonium production becomes in the targets. That becomes a waste material. We get rid of our waste in commercial low-level waste burial sites. If we have more plutonium, we would have to be very careful about how much is there and whether we could continue to dispose of our material in low-level waste burial sites.

So, that is a fish hook in the line that we don't have a good handle on yet.

Then there is the minor issue that the hardened flux will increase neutron damage in NTD silicon. It is minor but it is real. We would have to either give up that as a process or perhaps find a way to anneal out the damage due to the fast neutrons, the higher percentage of fast neutrons.

Very briefly I would like to get into what the impact would be if we had to convert to low enriched uranium for our isotope targets. As I mentioned, we use right now enriched uranium, 93 percent U-235, to produce the isotopes. If we had to convert to LEU, I think that would be the end of the game for us.

Right now, we don't have the technology for chemically separating these isotopes from low enriched targets. It would require a substantial amount of development work to work this out. It is a chemistry problem. Right now we know how to do it by using high enriched targets but we don't know how to do it using low enriched targets.

CHAIRMAN PALLADINO: What sort of traffic do you have in high enriched uranium targets, it is a sizeable sum?

MR. McGOVERN: Yes. It is tens of kilograms.

CHAIRMAN PALLADINO: What?

MR. McGOVERN: Tens of kilograms throughput per year.

There is a chart there that nominally compares the characteristics of a high enriched target as we now irradiated in our core with what we could possibly do with a low enriched target.

The two significant values there would be the Mo-99 yield per target. Whereas now we can produce 360 curies we would be reduced to 144 curies per target with a low enriched target.

There is a hooker there in that we are not certain whether we could make a 100 milligram per square centimeter target. There is an electroplating process that would have to have some work on it in order for us to achieve that loading, that density.

The other significant number, as I mentioned before, is the plutonium content. Right now in our targets we produce 10 to 20 micro curies -- the curies should come out of there, that's not correct -- 10 to 20 micro curies of

IMPACT OF
HEU/LEU ISOTOPE TARGETS

1. TECHNOLOGY DOES NOT EXIST FOR CHEMICAL SEPARATION PROCESS OF LEU TARGETS. (SUBSTANTIAL DEVELOPMENT IS REQUIRED TO DEVELOP NEW CHEMICAL SEPARATION PROCESS.)

2. COMPARISON OF OPERATING CHARACTERISTICS IN UCNR CORE.

	HEU	LEU
ENRICHMENT	93	20
NOM. WGT./GMS. U-238	1	24
NOM. WGT./GMS. U-235	15	6
NOM. WGT./GMS. TOT. U	16 (50 MG/CM^2)	30 (100 MG/CM^2)
MO-99 YIELD	360	144
PU-239 (UCI)	10 TO 20	250 TO 500

3. COMPARISON OF OPERATING COST.

VARIABLE COST OF PRODUCING MO-99 WOULD INCREASE BY APPROXIMATELY 2.4.

TOTAL COST WOULD INCREASE BY APPROXIMATELY 1.7.

SMALL REACTOR SUCH AS UCNR COULD NOT COMPETE WITH HIGH POWER TEST REACTORS.

plutonium 239 per target. If we had to convert to low enriched uranium, that would go up to 250 to 500 micro curies per target.

And the uncertainty there is involved in this residence integral where the hardened flux changes a cross-section, where the cross-section changes from what it is now to what it would be with the new core.

The comparison of the operating cost for Mo-99 production alone -- let's take that one as the benchmark -- the variable cost would be increased by a factor of 2.4 to our best knowledge right now. The total cost would be increased by almost a factor of two, and we believe that the small reactor -- such as the Union Carbide reactor in Tuxedo -- could not compete with any of the higher-powered reactors that produce this product.

In summary, if conversion to LEU fuel becomes mandatory, the conversion of the UCNR must be with the silicide fuel. It would have to be a gradual conversion so that we could maintain continuity of operation. Gradual meaning incremental, changing fuel as it burns out.

The operating costs will rise if there is no cost advantage in conversion.

If the thermal flux is reduced, we probably can -- if the thermal flux is reduced in the core, we could not hope to get a better fuel that would give us the economy of

SUMMARY

IF CONVERSION TO LEU FUEL BECOMES MANDATORY:

(A) CONVERSION OF UCNR MUST BE WITH U_3Si_2

(B) CONVERSION MUST BE GRADUAL OR INCREMENTAL.

(C) OPERATING COST WILL RISE IF THERE IS NO COST ADVANTAGE IN CONVERSION.

IF THERMAL FLUX IS REDUCED IT WILL BE IMPOSSIBLE TO COMPENSATE FOR ADDED COST BY BETTER FUEL ECONOMY.

IF CONVERSION TO LEU TARGETS BECOMES MANDATORY:

UCNR COULD NOT COMPETE WITH OTHER PRODUCERS.

AT LEAST, THE SUPPLY OF MEDICAL ISOTOPES WOULD BE LESS RELIABLE.

AT WORST, THERE WOULD BE A SHORTAGE OF MEDICAL ISOTOPES.

operation to overcome that increased cost of isotope production. We could probably overcome the cost of conversion by getting a longer-life fuel. But we could not overcome the cost of, the added cost of the isotope production.

If the conversion to LEU targets would become mandatory for the Tuxedo reactor, we could not compete with other producers and if we had to shut --

CHAIRMAN PALLADINO: Who are some other producers that you could not compete with?

MR. McGOVERN: The primary competitor is the Atomic Energy of Canada, Ltd. There is a European producer in Belgium, I.R.E., and then there is a producer in Australia, the Australian Atomic Energy Commission.

CHAIRMAN PALLADINO: Do they use LEU?

MR. McGOVERN: I believe they all use high enriched uranium at this time.

CHAIRMAN PALLADINO: Okay, thank you.

MR. McGOVERN: Thank you.

CHAIRMAN PALLADINO: We appreciate your presentation. Any other questions? Okay.

Now, let's see, we did promise Mr. Leventhal three to four minutes. Would you like to come forward? We would appreciate your being brief in view of the lateness of the hour.

MR. LEVENTHAL: Mr. Chairman, I thank you very much, and also the members of the Commission to permit me to speak for just a few moments.

My purpose is not to testify today because we really didn't prepare any testimony, not having been alerted to this meeting until the public notice came out.

Basically, my purpose on behalf of Nuclear Control Institute, which is an organization that deals exclusively with the nuclear weapons proliferation problem is to ask that the Commission hold another meeting to hear from experts in the area of nuclear weapons design and nuclear weapons nonproliferation as to the significance for converting research reactors -- I should say not converting all domestic research reactors to low enriched uranium.

As you know, there is a licensing proceeding under way at UCLA to discuss this issue in connection with that particular reactor. As I understand it, that may be one of the research reactors that would be exempted from the requirement, based on some of the considerations raised at the meeting today.

We would propose that a member of our board, Dr. Theodore Taylor, a former weapons designer, one who helped design the trigger reactor and a specialist on nuclear safeguards and physical security, be invited to testify, and there are others as well, Pete Scoville, the president of the Arms Control Association, former Assistant Director of AGDA and the CIA, whose views also, I would think, would be of considerable interest to the Commission.

One concern we have, frankly, is that you appear not to have had a briefing on some of the safeguards and foreign policy from those parts of the Commission staff that could provide some insight -- and I am referring to the International Programs Office and your own Safeguards Office.

I believe, as Commissioner Gilinsky alluded to, you would also want to hear from ACDA, the State Department, from the DOE Defense Program's office as to what some of the serious arms control questions and implications are in this particular matter before you.

It would be wise, I think, to make a distinction between the domestic side and the foreign policy side of this. What the United States does with regard to its own domestic program is going to bear quite heavily upon how other countries are going to respond to our efforts to get them to switch their research reactors from highly enriched to low enriched fuel.

It would be ill advised, I think, to come to any decision without taking into full consideration that particula matter.

So, we would ask that before you go to a proposed rule-making, that you do have at least one more meeting on the subject to consider the questions that I have just alluded to, both from within your own agency as well as other agencies, and to allow outside witnesses to testify.

I would direct your attention to the declarations made in the UCLA case by Pete Scoville and Dr. Theodore Taylor, as well as David Hafemeister who previously worked for Senator Glenn and was in the State Department during the last administration, and is a physicist.

But these are matters which should be brought publicly to the Commission's attention here in Washington, not simply to a Licensing Board in California, and we would hope that you would do this before taking any further action.

CHAIRMAN PALLADINO: Well, thank you very much for your comments.

Well, I am going to propose that we ask the Commissioners to re-examine this staff requirements memo that we had before and see if they have some modifications.

I would also propose that we do set up another meeting in which we look at the safeguards and foreign problem of the implications of what we do.

COMMISSIONER ASSELSTINE: Yes, I think that is a good idea.

MR. LEVENTHAL: Thank you.

CHAIRMAN PALLADINO: Is there anything more that should come before us this afternoon?

COMMISSIONER BERNTHAL: Well, if I could just make the inquiry here. I wonder, based on what we talked about, whether it would not be good to have a classified briefing, perhaps, on some of these --

CHAIRMAN PALLADINO: It may have to be, yes.

COMMISSIONER BENRTHAL: For example, it is still not clear to me exactly -- apparently there is some sort of curb of ease of explosive production as a function of uranium enrichment where plutonium is a problem on one end and enriched uranium is the problem on the other.

I don't have a good feel for that. The ease of diversion at domestic and foreign sites. I think there are a number of questions here that --

CHAIRMAN PALLADINO: Well, I think the extent to wnich things will have to be classified we will put in a classified meeting, and then I think anything that we can open up for public participation --

COMMISSIONER ASSELSTINE: Right.

CHAIRMAN PALLADINO: We will try to explore that.

All right, thank you very much. We stand adjourned.

(Whereupon, at 5:20 p.m. the meeting of the Commission was adjourned.)

CERTIFICATE OF PROCEEDING

This is to certify that the attached proceedings before the

NRC COMMISSION

In the Matter of:Briefing on Development of Proposed Rule on HEU At Domestic Reactors

Date of Proceeding:Mondav, December 19, 1983

Place of Proceeding: Washington, D. C.

were held as herein appears, and that this is the original transcript for the file of the commission.

Elizabeth Hansen
Official Reporter - Typed

Elizabeth Hansen
Official Reporter - Signature

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

- - -

COMMENTS ON IMPLICATIONS OF A

PROPOSED RULE REGARDING USE OF HEU

IN DOMESTIC RESEARCH REACTORS

- - -

PUBLIC MEETING

- - -

Nuclear Regulatory Commission
Commissioners' Conference Room
1717 "H" Street, N. W.
Washington, D. C.

Friday, January 27, 1984

The above-entitled open Commission meeting convened, pursuant to notice, at 11:33 o'clock a.m., NUNZIO J. PALLADINO, Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

NUNZIO J. PALLADINO, Chairman of the Commission

VICTOR GILINSKY, Member of the Commission

THOMAS ROBERTS, Member of the Commission

FREDERICK BERNTHAL, Member of the Commission

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

S. CHILK
S. TRUBATCH
T. TAYLOR
P. LEVENTHAL
D. HIRSCH

AUDIENCE SPEAKERS:

D. ALBRIGHT

PROCEEDINGS

CHAIRMAN PALLADINO: Good morning, ladies and gentlemen. The Commission is meeting this morning to hear a discussion on the implications of possible rules regarding the use of highly enriched uranium or HEU at domestic research reactors. This is a follow-up meeting on this subject that resulted from a meeting last month when we heard from the NRC staff, representatives of the operators of research reactors and from the Department of Energy.

At the end of that meeting we heard briefly from Mr. Paul Leventhal of the Nuclear Control Institute. We subsequently agreed to his request to provide him and Dr. Taylor with additional time to address the Commission in order to deliberate on his organization's concerns.

In addition, we agreed to a request to hear from a representative of another group, the Committee to Bridge the Gap, and Mr. Dan Hirsch of that group is with us today. Before we begin, do any of my fellow commissioners have any additional opening remarks?

COMMISSIONER ROBERTS: It is not a remark but a question. How long is this going to last?

CHAIRMAN PALLADINO: This was scheduled from 11:15 to 12:00. We started 15 minutes late. We will try to terminate it as soon as possible after 12:00 but no later than 12:15.

COMMISSIONER ROBERTS: I have to leave at 12:15. If I leave it is not because of any lack of interest in any of you of what you are saying. I have a previous engagement.

COMMISSIONER GILINSKY: Tom and I belong to a lunch party.

(Laughter.)

CHAIRMAN PALLADINO: I should indicate that I have another urgent matter I have to address so I will leave the meeting for a few minutes but I will try to be back as soon as possible.

Let me then turn the meeting over to Mr. Leventhal.

MR. LEVENTHAL: Thank you, Mr. Chairman. We anticipate finishing up on time. We don't believe it should take longer than 45 minutes for each of us to make a brief presentation and, of course, to respond to any questions that you might have at any point along the way.

(Whereupon, at this point in the proceedings at 11:38 o'clock a.m., Chairman Palladino exited the meeting.)

MR. LEVENTHAL: I thought the way we might organize this within the 45 minute time frame is that Dr. Taylor will speak first on the weapons implications of the question being addressed in your proposed rule applying to domestic research reactors and also some of the security questions that these weapons implications raise.

Mr. Hirsch will then deal with actional security problems encountered at the sites of various research reactors in this country and he will also provide a brief critique of the LEU conversion study group's report that was submitted previously to the Commission.

I will wind up by addressing some of the non-proliferation policy implications of the domestic rule by the NRC on the question of converting domestic research reactors.

So without further ado, we will start with Dr. Taylor.

MR. TAYLOR: With the Commission's permission, I would like to summarize the statement I submitted earlier this week. I have come to a conviction that all things considered highly enriched uranium, plutonium and uranium-233 are the most dangerous substances on earth.

I say this because separately or in combination these materials are the essential or the required ingredients of nuclear weapons and the threat of destructive use of these weapons is the greatest danger that humanity has ever faced.

The knowledge and skills that are required for the design and construction of nuclear weapons given access to the needed amounts of nuclear weapons materials, these three separately or in combination, which incidentally do not exist in significant quantities in nature, given those materials, the information, the knowledge, the skills, the non-nuclear materials necessary for construction of nuclear weapons are distributed now worldwide and all of these attributes necessary for making weapons are spreading rapidly.

The only realistic hope that I see for stopping the further spread of nuclear weapons quite possibly into the hands of terrorists as well as nations that don't now have nuclear weapons is to restrict the uses of nuclear weapons materials to those uses for which the benefits clearly out weigh the risks of their destructive abuse.

I cannot conceive of any uses of research reactors fueld with highly enriched uranium for which this criterian is met. I therefore strongly urge the Commission promptly to rule that all domestic research reactors under its licensing authority be required to convert from highly enriched uranium to low-enriched uranium fuels as soon as the low enrichment fuels are available.

I also urge that exceptions to this ruling be made only when such conversion is not possible and also the NRC is convinced that the national benefits of use of such reactors clearly outweigh the risks of theft or diversion of the fuel materials.

What I mean by "outweighing the risks," I mean not just outweighing the risks that would involve some kind of a nuclear theft or nuclear abuse of these materials but also the risks that would be run in setting out to try to prevent such diversion. By that I mean risks that the character of the operations at a place where research reactors with highly enriched uranium is becomes so troublesome for the operators that they finally decide that they just can't meet adequate safeguards requirements because of costs, inconvenience and general difficulty and have to discard the whole system.

In opposition to these proposed rulings, it has been argued that the quantities of highly enriched uranium that are used in research reactors are too small to prevent a significant threat of their abuse in nuclear weapons.

A thorough public discussion of this matter is not possible because of security restrictions. Furthermore, the minimum quantity of highly enriched uranium needed to make a nuclear explosive is not unambiguously definable. There is no number that says below that quantity of highly enriched uranium you cannot make a fission bomb except zero. This quantity depends on the knowledge, the skills and the intent of those designing and fabricating the explosive.

The quantity needed can be considerably smaller than the 20 kilograms that is often cited as the critical mass of highly enriched uranium in a good reflector. In a lot of analysis of this question, that is the point of departure.

COMMISSIONER GILINSKY: Some of the research reactors do involve the use of material --

MR. TAYLOR: Greater than 20 kilograms.

COMMISSIONER GILINSKY: Yes or roughly in that range.

MR. TAYLOR: Yes, I understand that.

COMMISSIONER GILINSKY: Many don't.

MR. TAYLOR: I just want to say to the Commission that the quantities that can be used under certain circumstances for making nuclear weapons can be considerably smaller than 20 kilograms. How much, I can't say here.

Furthermore, a black market in nuclear weapons materials could provide inducements to theft and subsequent sale of any quantity of highly enriched uranium for which the anticipated sale price is deemed to be worth the risk of the theft.

It is pure speculation to say what the black market might draw in dollars per kilogram. It is not inconceivable to me at all in view of the kinds of leverages that could be used with a nuclear explosive to say that prices well above $100,000.00 per kilogram might be credible if people could actually transfer that to people who want it.

All these considerations leave me greatly concerned about the possibility of theft of as little as one kilogram of highly enriched uranium which is generally only a fraction of the quantity that is used to fuel research reactors.

Now in this connection I would like to point out to the Commission something that I did not point out in my testimony and that is that the existence of the commercial market for highly enriched uranium fuel for research reactors automatically generates a need for fuel fabrication plants where considerable quantities of highly enriched uranium would be present much more than would be present at the research reactors themselves.

In other words, a continuing market in highly enriched uranium generages a funnel at the front end of what happens at the research reactor in which there are large quantities typically of unirradiated uranium fuel very often in metallic form prior to its being combined with aluminum, for example, to make materials test reactor type fuel plates.

COMMISSIONER BERNTHAL: What you are saying is that at least domestically then you are much or more concerned about the suppliers and the safeguards that might attach to the supply as you are about the site that the reactor itself is on.

MR. TAYLOR: That is correct. I don't want that to be interpreted as saying I am not concerned about the sites themselves.

COMMISSIONER BERNTHAL: I understand.

MR. TAYLOR: I am even more concerned about the fuel fabrication plants. Now such plants need to be safeguarded I would say just as matter of prudence in such ways as to prevent any credible attempt at theft or diversion of highly enriched uranium in quantities of a kilogram or more to be successful. By any credible threat I mean any that any group of experts might propose to another group of people who would then sit back and ask, "Does this sound reasonable as a thing that people might actually do in the light of what has happened in the past and major robberies and so on?"

I am not at all sure that commercial fuel fabrication plant operators are willing to install those necessary security measures.

COMMISSIONER GILINSKY: Then tend to be to the extent that they use quantities greater than these formula quantities, five kilograms of material, and they would if they were fabricators, would be subject to the more severe security requirements of the Commission.

In the case of the research reactors, we give rather generous credit and I think overly generous credit, to the self-protection attribute of slightly irradiated fuel. So the protection at the universities and at the research centers is rather less.

MR. TAYLOR: I think for purposes of this hearing that that should really get the focus. It is the reserach reactor. I am just pointing out the existence of the research reactors trigger --

COMMISSIONER GILINSKY: It certainly implies something upstream.

MR. TAYLOR: -- the need for more massive safeguards.

COMMISSIONER GILINSKY: Right.

MR. TAYLOR: I have to say that I don't know as of this moment what security measures are in force in the fuel fabrication plants that now produce this material. I have known what it was in the past and I would just call them grossly inadequate to meet threats on the scale much less sophisticated than have succeeded in stealing money, gold, dope, among other things.

COMMISSIONER BERNTHAL: You say that you have been aware of the security procedures and percautions in the past, how long ago is that that you are aware of?

MR. TAYLOR: Back to the early 1960's when I was at General Atomic I was concerned about something that is no longer there.

COMMISSIONER GILINSKY: There is no question that security was far below what it should have been at that time and it has been upgraded in those areas.

MR. TAYLOR: It has been upgraded and I think substantially. The last time I knew in detail what the security measures were was in the 1960's.

COMMISSIONER GILINSKY: I can't resist telling the story. I went through one of these places years ago and I went through the vault and there were many, many, many millions of dollars worth of highly enriched uranium. I won't tell you how many and I pointed this out to the manager and he said, "Boy, if it were money, we would sure guard the hell out of it, wouldn't we?"

(Laughter.)

MR. TAYLOR: Just to sum up the main thrust of my testimony in a sentence or two, I would simply say that the technical advantages of using highly enriched uranium in a research reactor rather than low-enriched uranium which for almost all reactors is a reasonable alternative, that these advantages at best were marginal leaving out any questions about the risks of diversion or theft.

If one gives even much less attention to the threat of abuse of these materials, it seems to me completely wipes out any justification for research reactors to be using highly enriched uranium not just in this country but everywhere.

In situations in which it should turn out that low-enriched uranium from which nuclear weapons cannot be made without further enrichment, in cases where there is not possible, then I think it really is encumbent on the Commission to look very carefully at whether the national advantages and benefits of operation of such a reactor with high enriched uranium fuel outweigh the risks of having to treat that as material that is highly dangerous.

The final point that I would like to make is that as far as I personally am concerned, the focus of attention should be generally worldwide on removing activities or stopping activities that require the use of highly enriched uranium for any purpose of any kind.

I am saying that because that is where I am coming from in this whole matter of what to do about research reactors. I am not just concerned about research reactors. I am extremely concerned about critical facilities which generally involve much larger quantities of these materials generally not in any even slightly irradiated form and, of course, the biggest concern of mine is the stockpiles of highly enriched uranium and plutonium that are now incorporated in the world's nuclear weapons.

Thank you. I would be glad to answer any questions now or if you would rather wait until the other members of this group have presented their testimony, that is fine, too.

COMMISSIONER GILINSKY: Have you looked at all at the question of self-protection of slightly irradiated fuel?

MR. TAYLOR: Yes. My conclusion from that is that self-protection is offered either by the routine use of the reactor for producing power or for very low power reactors placing the fuel in some kind of a chain-reacting system that has much more neutrons that that categorically and generally is not sufficient protection. That is based on real numbers which have to do with the radiation dosages at a few feet from fuel bundles that have been quite highly irradiated.

It is one thing to say that one is going to protect workers and the general public from radiation and it is another thing to say that terrorists or criminals or strongly motivated people working on the military uses of nuclear explosives will be deterred by anything approaching these low levels.

I would say categorically that to be an effective deterrent the lives of the individuals that are going to be manipulating these materials would have to be highly at risk and even in those circumstances --

COMMISSIONER GILINSKY: As they would be in dealing say with power reactor commercial fuel. There they are dealing with the material which is extremely highly irradiated and dangerous.

MR. TAYLOR: Power reactors are a different matter.

COMMISSIONER GILINSKY: I don't know what the numbers are exactly in terms of rads but I know that the standard that we apply in research reactors is 100r per hour at three feet, I guess it is, which is a rather low level of radiation.

MR. TAYLOR: It can be cut down dramatically by use of very simple and ordinary light shielding materials if that is deemed necessary.

MR. LEVENTHAL: Let me just say we have some figures on that and Mr. Hirsch will present them in his presentation.

COMMISSIONER GILINSKY: Oh, he will. I see. All right.

COMMISSIONER ROBERTS: Would you venture an opinion on whether you think the National Bureau of Standards reactor, the benefits might outweigh the associated risk?

MR. TAYLOR: If fairness to the --

COMMISSIONER ROBERTS: That may not be a fair question.

MR. TAYLOR: -- question, I don't know enough about what it is used for to be able to say. I, however, will venture an opinion and a guess that if one really looks at the total set of benefits of using that reactor and the total risks of using that assuming that it is possible for people to conceive of a theft attempt that does sound credible, then I would say no, that the advantages do not outweigh the hazards.

COMMISSIONER GILINSKY: I think it is worth pointing out that we are faced with a variety of reactors, research reactors. There are 24-odd reactors at universities, most of them at small or low-power end of the spectrum and there are two or three that could be considered fairly substantial ones. Then you have several larger ones in the government that are licensed such as the NBS reactor at government facilities and I think there are a few commercial ones.

Those tend to be the ones that are more difficult to change over to LEU at the present time in that the fuel technology is not readily available and to the extent that there are not government facilities more plausible that there be adequate safeguarding and so on, I myself feel most strongly about changing over the university reactors.

There, it seems to me, one isn't going to get adequate security and there is just much less reason to have this kind of material at those reactors.

MR. TAYLOR: As a matter of priority, I would certainly agree that the research reactors, particularly the low-power reactors, be subjected to this ruling first and as rapidly as possible.

I see no excuse whatever for using high enriched uranium in universities.

COMMISSIONER GILINSKY: I just don't believe it belons on the campuses.

MR. TAYLOR: I also would like to point out that as I understand it the way the process generally works the institution that applies for the license or is involved in applying for the license and actually is concerned with these matters is not generally the institution as whole and I think the risks that are involved in the use of these materials are such that at a university, for example, the university as a whole, the administration of the university should be thoroughly aware of what the risks are and what the alleged benefits by the department or whatever that wants this reactor because I think in many cases you would find a different view of the institution as a whole toward the need for highly enriched uranium than you have, for example, from the nuclear engineering department.

COMMISSIONER BERNTHAL: If I could interrupt, let's make clear what the problem is though from the standpoint of I believe from what we have heard of most university research workers having spent a little time there myself in my previous life.

I agree with you on your comment on the significance really of highly enriched uranium to the research capabilities. We heard nothing in testimony and I think we all understand that in terms of neutron fluences or almost by whatever measure you might choose, there is not great significance to low-enriched uranium in principle can do the job very nearly as well for almost any imaginable experiment but the question really is money. Therefore, I would hope that all of you who are concerned about what real problem there may be and the symbolic problem there may be and I would like some of you to comment on that issue as well that you recall that we here do not have the power of the purse over providing the funds to the universities to make the conversions that we might deem desirable.

Most universities don't have those funds readily available. So in some cases you have individuals whose research programs to a large extent may depend on whether or not they are forced to carry out this conversion and whether the funds are adequate. If the funds are adequate, I suspect we would great cooperation and perhaps even delight in making the conversion.

So I would just urge that you have a further job to do in this city besides the role of the NRC convincing us of the necessity of our role there.

MR. LEVENTHAL: If I could just briefly respond to that. I understand that the Commission received a letter yesterday or today from a number of Congressmen pledging to work to get the funds necessary.

The estimate for conversion, I guess the official estimate or at least the one contained in the study group report, was $15 million dollars which is not a terribly large sum.

COMMISSIONER GILINSKY: Over a period of five or more years.

MR. LEVENTHAL: Yes, that is correct. But at least in relative terms it is not a very large sum when it comes to nuclear matters.

COMMISSIONER GILINSKY: I want to make clear that it is that amount spread out over a period of several years.

MR. LEVENTHAL: Right. So I would think that it shouldn't be all that difficult to get Congressional support.

COMMISSIONER GILINSKY: When you think about the amount of money that would get spent even if a subcritical amount of material were stolen and we have to think about dealing with that, we would then have to change the limits on all the existing facilities, reduce them because you could no longer afford to lose the other half and God knows what would happen at that point, whether the facilities would even be allowed to operate.

COMMISSIONER BERNTHAL: I agree with you. It is a very small amount of money but I would also recall for you that sometimes a few hundred thousand dollars can cause a research facility to be shut down if the universities had to cough up the money.

COMMISSIONER GILINSKY: I think the matter of money is a terribly important one. I don't know that these are exactly the right people except insofar as urging them to go talk to others as well.

COMMISSIONER BERNTHAL: That is exactly my point.

COMMISSIONER GILINSKY: But I think it is an essential item here whether it goes in the DOE budget or our budget or wherever, I think more naturall it would go in the DOE budget, but at least part of it could be handled here, I think. These reactors by in large have been subsidized by the government over the years and I think it is an extremely good investment in avoiding just a whole lot of trouble.

MR. TAYLOR: I guess I have to say that if the alternative is adequate safeguards for these materials at the universities, the DOE or whatever government institution does even if they provided the money to make the conversion, it would be a huge bargain compared to real money coming out of the federal budget that would be required for the safeguarding.

MR. HIRSCH: If I could add to that, the cost of having simply one guard on an eight-hour shift, adding that to the security of these facilities with weapons-grade material would be greater than converting each of the facilities even if you buy the cost estimates that you received a month ago from the research reactor operators. I feel that those cost estimates are high by a factor of two or three.

Even if you accept the $15 million dollar figure which I think is very high, that is about a third of what the reduced enrichment program is supposed to spend on research and development for those fuels. So if you are willing to research it, you certainly ought to be willing to put up the money to be able to convert them and I think the bottom line is what would be the consequences if some of that material were stolen.

I would like if I could to answer a question you raised earlier about the 100 rem matter.

COMMISSIONER GILINSKY: Please.

MR. HIRSCH: If I could have my viewgraph.

(SLIDE.)

MR. HIRSCH: This is a reference on a research reactor,anything below one megawatt and based on an average operation at many of these facilities it is just a few hours per week. You will see that the dose rate per bundle goes down after eight hours to about 92 rem per hour after just eight hours of shutdown. Remember that they only run let's say on a Monday and maybe on a Friday. In one day it goes down to 33--

COMMISSIONER GILINSKY: This is what? At some standard distance?

MR. HIRSCH: At three feet unshielded from a bundle as the rule requires. In one week it goes down to 11 rem per hour, at the end of four weeks down to 6.5. The Los Alamos study prepared for you some months ago estimated that to steal all the weapons-grade material at the average research reactor would take 1.25 hours. Therefore, the dose would be roughly the same as the dose per hour per bundle and if there were several people doing the theft, each individual would get less dose than the radiation workers within the industry permitted per year under your regulations.

So it is a very small amount of radiation for most of these reactors and it provides no deterrent really whatsoever for theft and for the use of the material for weapons.

I wanted to give a feel also for --

COMMISSIONER GILINSKY: Let's see. In order to qualify for the reduced security that 100r allows you per feet, don't they have to stay over that 100 hour at all times at least in principle?

MR. HIRSCH: In principal, yes. Unfortunately there have been rather lax enforcement of that and some people in the Safeguards Branch have interpreted your regulation to mean 100 rem per hour for the entire core rather than for each readily separable element as required by the regulation.

Therefore, there have been a number of facilities that we found that were way below the 100 rem but had been given for years the exemption even though they weren't entitled to it. This is the figure per bundle and we will give you a feel for how lightly irradiated that fuel really is.

COMMISSIONER BERNTHAL: Just for the record and what you are saying is, I think, significant but 10r per hour at three feet and that is if you assume these things get shut down perhaps for a few days on the average is still close to 100r per hour at one foot. You are three times closer so it is roughly ten times as much. Therefore, you should point out that that is still a pretty hefty dose. I mean 600r is a 50 percent lethal dose, I think, in usual parlance so it is not like it is a trivial amount.

MR. HIRSCH: Excuse me. This is at three feet as required under your regulations.

COMMISSIONER BERNTHAL: I understand. I am just saying that if you talk about getting as close as one foot, you are already up to a very high radiation level.

MR. HIRSCH: But you will notice that in your Los Alamos report they assumed that one would be at least three feet because that is the easy way to steal material. You had a study done that estimated the doses even if were at 100r per hour at three feet would average considerably less than 100-rem per hour per person.

That is when you have each bundle being 100-rem per hour at three feet.

COMMISSIONER BERNTHAL: So if you are at three feet, the presumption is that you have some minor remote handling capability to steal the stuff.

MR. HIRSCH: Yes.

COMMISSIONER GILINSKY: This is really kind of a reference calculation. It could either way.

COMMISSIONER BERNTHAL: I understand but I just wanted to put the numbers in perspective.

COMMISSIONER GILINSKY: You can either get closer or you could have sort of shielding which would reduce them.

MR. HIRSCH: This is given your regulations at three feet. I wanted to try to give a feel for how this material is at a number of research reactors and I wanted to particularly stress a matter that Dr. Taylor mentioned in his written statement which is the amount of material you need for a weapon goes down as the square of the implosion. So the figures that you have receieved for how much you need or for normal density weapons and if you use an implosion device you need much, much less and I think that should be kept in mind.

COMMISSIONER GILINSKY: Square of the density.

MR. HIRSCH: So if you increase density by two, you need one-fourth the material, by three, one-ninth. So very small amounts of material are potentially dangerous. Now what about a reference --

COMMISSIONER GILINSKY: That is not so easy to do.

MR. HIRSCH: I will leave that to my cohort here as to how easy.

Now is this material kept at the facilities and why are you faced with security that is adequate to protect it against theft or converting it to something not worthy of theft? If I could have the other viewgraph for a moment.

(SLIDE.)

MR. HIRSCH: You had a proposal before you from the research reactor community which said that your August 1982 policy of converting facilities to the maximum extent possible should be enforced by only doing two things, requiring only new research reactors to convert and requiring only reactors that do not have what they call "lifetime cores" to convert.

That means exempting almost all research reactors except three to five. It would really mean gutting your August 1982 policy. I would like to show you why that is. Here is a sample lifetime core as defined by the research reactor community.

The normal fuel loading is something like 3.5 kilos in the core. As I indicated that material is not over 100-rem per hour at three feet unshielded. In addition, the reference reactor would have some lightly irradiated fuel in storage usually in little storage pits and then some fresh fuel either in a storage pool or in a storage room.

Now their definition of lifetime means that over the next 15 to 20 years they would not need to order new fuel, that either the fuel in core, the fuel in storage or fuel currently on order would be sufficient to get them to the year 2000. That basically would mean if you accepted their proposal that for the lifetime of these facilities they would have highly enriched uranium on-site available for theft.

It would mean that your policy of converting to the maximum extent possible was gutted if we only converted three to five and left the rest of them with this material on site. How is that material on site? How is it kept? The basic security for most of these university reactors and we have reviewed about a third of them, simply a normal burglar alarm system tied into campus police.

In one NRC inspection report for an East Coast reactor they found that at times there was only one campus police officer available to respond and no procedure as to what to do, no procedure as to whom to call on for assistance. The general protection is essentially that of any protection at a university reactor.

COMMISSIONER GILINSKY: This is because they stay below the five kilogram level.

MR. HIRSCH: If you look carefully at 7360 and 67 there is very little difference explicity in those regulations. I am referring both to below 5,000 and above. The only real difference if you are above is entrance searches.

COMMISSIONER GILINSKY: That doesn't sound right to me. Are you talking about a research reactor specifically?

MR. HIRSCH: Generally. The difference between the requirement for a research reactor that has below 5,000 grams and above, there is very little difference explicitly laid out in the regulation as to the level of protection.

COMMISSIONER GILINSKY: Our standard requirements for fuel facilities and so on that have larger quantities of material are fairly formidable and in fact if applied to these research reactors would put most of them out of business if not all of them.

MR. HIRSCH: That is the frightening thing. A few years ago you produced a safeguards upgrade rule that substantially increased security at the fuel cycle facilities with more than a formula quantity but the research reactors with more than a formula quantity were exempted from that. It was a deferral and that deferral was tied into the proposal to reduce enrichments.

The argument that came before you was that it is going to take a couple of years to come up with the fuels to convert this deferred research reactor upgrading security for that time until we can convert them. That interim rule is extremely weak and, in fact, now you have a proposal to reduce even further the requirements if you have more than 5,000 grams.

COMMISSIONER GILINSKY: Certainly there is basically this concern that leaning harder on the universities would put the facilities out of business that has in effect led the Commission to give considerable credit to things like irradiation of a fuel and so on in setting the safeguards requirements.

I think we basically have to look at the material and the danger it poses and work from that and nevermind what the auspices are.

MR. HIRSCH: That, I think, is the situation we face. I teach at a university. I know the situation there. We want an open atmosphere. We are an institution that wants to feel that we have an open environment. The kind of security measures necessary to protect bomb materials simply won't fit with the university and that is why the universities are reluctant to have the security necessary, have come in for exemptions from that security and why the Commission has said, "Okay, if the environment is such that you don't really can't protect it, let's get the stuff off and do everything you want to with LEU fuel and it isn't a threat if stolen."

Let me just say that our review of about a third of the research reactors with HEU indicates that we have not found one where it would not be relatively easy to steal kilogram quantities of HEU. The burglar alarm systems are extremely easy to by-pass. The campus police don't know how to respond. In one case a reactor had its burglar system tuned down so far because they kept having false alarms that an inspector came in, set the alarm and was unable to set the alarm off because the sensitivity was so far down.

You have published, in fact I have brought a few of them, manuals that would indicate how one in fact would by-pass these alarms. They are generally to help the facility realize what the threat might be and cover for it but anyone who reads them also knows how you can quickly by-pass any of the lines sensing devices.

COMMISSIONER BERNTHAL: Let me ask one question as a matter of idle curiosity. Has there ever been a record, students do silly and dumb things occasionally, of anyone making off with any of this material or attempting to make off with it?

MR. HIRSCH: There have been break-ins where people came and left notes saying, "Just wanted to show you how bad your security was." That has happened at several research reactors.

COMMISSIONER BERNTHAL: But to your knowledge nobody has ever --

MR. HIRSCH: Stolen the stuff.

COMMISSIONER BERNTHAL: -- been able to make off with any of the material.

MR. HIRSCH: I guess what I am telling you is that if someone did that, that would be for the research reactor community what TMI has been to the power reactor community.

COMMISSIONER BERNTHAL: I suspect you are right.

MR. HIRSCH: This is what we are trying to prevent. We are trying to prevent it now before it happens. The amazing thing is that this is a sweet technical fix. No one is saying shut the facilities down. No one is saying don't let them do what they are doing. We are saying let them do everything that they are doing, simply pull out HEU and insert LEU and do everything you want. There is no threat of theft any more. It is a beautiful, sweet technical fix and if one doesn't do it, I am very concerned that we will have a scenario that you mentioned but not by somebody doing it as a prank but by somebody doing it to acquire a clandestine fission explosive.

COMMISSIONER GILINSKY: What is your assessment of what can be done today on the basis of the technology?

MR. HIRSCH: You could convert all of them today aside from maybe those two that have come for exemptions to you with a few of them having to change plate spacing, what they call major license amendment and it is not very major. Within two years, you could convert all of them. You could convert perhaps half of them for free fuel costs based on SPERT LEU fuel that is free sitting at The University of Florida. They have 5,400 LEU pins that they are using to convert their own facility but that is many times more than they need. The cost would be in my view five to seven million dollars even if you didn't use the SPERT fuel for everything and you could convert them easily today.

I must remind you that these research reactors when originally designed were designed for LEU. They ran them on low-enriched uranium originally. They have since converted them to HEU so it is nothing much to convert them back. It would take very little time. We are talking about shutting the reactor down, pulling the fuel out, putting in new fuel. They have come before you and told you it would take 120 months. That is just really nonsense. It would take a few weeks to convert, a few weeks to do a safety analysis and a very small amount of money.

Your policy of August of 1982 which was internationally acclaimed, it was a commitment to this international effort to reduce enrichment and as Paul Leventhal will indicate we can't expect foreign operators as has been said over and over again to convert if we basically have exempted almost all research reactors in our country from conversion.

COMMISSIONER GILINSKY: We ought to give a plug to the Department of Energy who has done a lot of the basic work here, at Argonne in particular which has provided the opportunity for doing this.

MR. HIRSCH: They deserve tremendous credit. We will have spent $50 million dollars to develop these fuels.

Let's spend a few million dollars to use them before it is too late.

COMMISSIONER GILINSKY: As have some of the commercial organizations, General Atomics and others.

MR. HIRSCH: I would like to give a plug to them particularly they, voluntarily, have stopped making HEU and now only have LEU and it made a number of conversions. I would also like to give a plug to the University of Maryland which ten years ago thought you might start requiring conversions and, for example, converted a plate type facility to TRIGA LEU. There have been a number of conversions already. They are easy. They are simple. They are sensible.

We are here to tell you, "Stick to your August 1982 policy."

MR. LEVENTHAL: If I could just reserve five minutes for non-proliferation.

COMMISSIONER GILINSKY: I think you have three.

COMMISSIONER ROBERTS: It looks like three to me.

COMMISSIONER BERNTHAL: Let me just say that you have touched on a point that, I guess, Paul it is probably your province to comment on and I would like to hear some comment on it and that is the relative significance that you attach to our whatever domestic safeguards and security requirements we might have versus the symbolism in the international arena of this action.

MR. LEVENTHAL: Let me deal with that and I will try to make it very consise. First, just to get a sense of the quantitative aspect of the problem, if we could have the viewgroup showing the exports by country.

(SLIDE.)

MR. LEVENTHAL: This represents all the highly enriched uranium also indicating the U-235 contained in it that has been exported through 1982 from the beginning of the "Atoms for Peace Program." You will see there that some 24 metric tons, almost, of highly enriched uranium containing almost 17 metric tons of U-235 have been exported.

Of that amount only about six to seven percent has been returned to the U. S. So you have to understand that most of it is still in foreign countries and therefore the civilian research reactor programs.

(SLIDE.)

MR. LEVENTHAL: The next viewgraph just shows by year the amounts of HEU that have been exported and the next one indicates the amount of U-235 contained in the LEU by year. The amount needed to meet foreign requirements is about 500 kilograms per year and there were a number of years where exports far in excess of that went out presumably to meet the lifetime requirements of the lower power reactors that were being built at that time.

COMMISSIONER BERNTHAL: Paul, if I might just interrupt. I had a couple of questions on the second graph. I didn't understand since you are graphing exports of HEU, does the cross-hatching mean then the fraction or the U-238 cross-hatching mean the fraction of U-238 that was contained in all of that HEU?

MR. LEVENTHAL: That is correct. On a relative basis. In other words, I should add and I am sorry I didn't at the outset, this material was prepared by David Albright of the Federation of American Scientists who is here today and could answer any specific questions on it. But I think I can answer that going back to the previous bar graph.

(SLIDE.)

MR. LEVENTHAL: That is intended simply to show the relative amounts of U-235 and U-238 by year contained in the HEU being exported.

COMMISSIONER BERNTHAL: What in the world happened in 1977 or do you know?

MR. LEVENTHAL: In 1977 I believe that resulted from a moratorium that was imposed temporarily by the previous administration to evaluate the whole program and exports were resumed but under much more stringent conditions whereby the quantities exported were such that the theft of any one quantity presumably would not provide an amount of material readily --

COMMISSIONER GILINSKY: I think he was asking why there was so much?

COMMISSIONER BERNTHAL: Yes, exactly. In 1977 it was three times what it was in 1975 and 1976.

MR. LEVENTHAL: David.

MR. ALBRIGHT: I can't remember exactly which country it went to --

COMMISSIONER GILINSKY: I think that was a shipment to the Federal Republic in one of their larger reactors.

MR. ALBRIGHT: -- Germany and it was a very large shipment.

MR. TAYLOR: Or a critical facility which accounts for a large fraction of that.

COMMISSIONER GILINSKY: Yes. I think you might point out that these are really a staggering amount of material in terms of their weapons significance.

(Whereupon, at this point in the proceedings at 12:16 o'clock p.m., Commissioner Roberts exited the meeting.)

MR. LEVENTHAL: They are staggering amounts of material and I think the thing that the Commission should bear in mind is that having gone on record as you have back on August 24, 1982 first in generally announcing your interest in reducing to the maximum extent possible the use of HEU in domestic and foreign research reactors and then stating at the conclusion of your Policy Statement that you were acknowledging that U. S. research reactor operators have shown little interest in converting to low-enriched fuel as part of a policy to strongly encourage conversion by foreign operators the Commission will take steps to encourage similar action by U. S. research reactor operators.

It really would appear then that the world will be watching very carefully what type of a domestic rule you promulgate and to make exceptions will simply invite other countries to do the same. I think you really want to bear that in mind particularly if one objective might be just to cover the university reactors because there we know that the security is most lax and the risk of theft is the highest.

If we do that here, we are inviting other countries to do the same and the security problems overseas may well be at least in certain countries far more severe than they are here. So you really are in a position to take a leadership role and it isn't only with regard to other countries.

The Department of Energy, I think, will be sensitive to the nature of the rule that you put forward and you must bear in mind that the NRC licensed research reactors use only ten percent of the total amount of HEU authorized for research reactors in this country. The other 90 percent are the 15 non-defense DOE reactors and the resistance you might well imagine is probably even greater within DOE to conversion of those reactors than is the resistance you are encountering from the university community.

So we would urge you to make no exceptions only perhaps in terms of time but not in terms of ultimate conversion of the research and test reactors. The U. S. policy should be strong and it should be unambiguous so that both foreign operators and operators of government reactors under the jurisdiction of DOE will be influenced to follow a very strong example.

MR. HIRSCH: If I might just add one point about that, the Government Accounting Office found as follows: "The lack of participation...", the General Accounting Office, "The lack of participation by U. S. facilities in converting to the new LEU fuel could undermine foreign acceptance of the new fuel and thus negate an important part of the U. S. non-proliferation objective."

So even if there were not a threat a theft from domestic reactors and I believe it is a very real threat because they are the least protected of our facilities, even if there were not that threat that very important effort that we are trying to make to convert foreign reactors could completely go under if we refuse to convert our own. They simply won't themselves.

COMMISSIONER GILINSKY: I must say that I generally agree with that. I participated in a meeting on this subject a few months ago, an international meeting, and it was clear that the foreigners were pressing pretty hard to convert their facility and are looking at us to do the same and didn't like being singled out. It is interesting also that there was a generally very optimistic view about the technological possibilities here that we do have the fuels to convert the reactors but they also felt that it was something that had to be done together and I agree with that.

MR. LEVENTHAL: Also in the far broader context of the amounts of uranium in the world and the potential as new technologies mature for enriching that uranium, anything that can be done now to delegitimate highly enriched uranium will have a very large non-proliferation benefit in the long run. The latest OECD estimate of the recoverable resource of uranium is something like 20 million tons today in the world. Potentially that has within it some 440,000 tons of U-235 enough for even conservatively estimating millions of atomic weapons.

If it were possible that highly enriched uranium were no longer required to fuel civilian research reactors and if no further production of HEU is required for the weapons stockpile or for the Naval propulsion fuel as may well be the case given the large amounts already produced, the basis would be established for suspending further production of HEU and even for blending down existing HEU stocks into low-enriched fuel for use in civilian and power programs.

So there really is a big picture here that is behind that what might appear to be a very narrow domestic rule. There is a lot at stake and we would hope that the Commission would take this very seriously in terms of the broad non-proliferation implications as well as the immediate concerns about the feasibility and the costs of converting domestic reactors.

COMMISSIONER GILINSKY: Thank you.

COMMISSIONER BERNTHAL: Thank you very much for your presentation. I would just like to comment that I for one would be delighted to assume a leadership role but not a leadership in seeing a large number of research facilities shut down and therefore, again I would urge that you take the lead in speaking with our friends over at OMB and DOE and Capitol Hill to see that the funds are provided that we can do what needs to be done here.

COMMISSIONER GILINSKY: I would add that this is the one area in the very vexing complex of problems we refer to as proliferation and nuclear terrorism and all of the related matters that really does have a technical fix and a relatively easy one thanks to the work done by DOE and others. We really ought to do what we can here.

MR. HIRSCH: If I might suggest the Commission can decide that it will convert these if the funds are available and urge the Congress to provide them and those of us in the non-proliferation community do our bit. The Congress is extraordinarily supportive of that program. It is a small amount of money in the scheme of things. It seems to me that the rule that should come out because it is only financial with no technical barriers, only financial, if the money is available all will be converted. It is very simple.

COMMISSIONER GILINSKY: Thank you very much.

(Whereupon, the above-entitled Commission meeting was adjourned at 12:24 to reconvene at the Call of the Chair.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the Nuclear Regulatory Commission

in the matter of: Comments on Implications of a Proposed Rule Regarding Use of HEU in Domestic Research Reactors -- OPEN MEETING --

Date of Proceeding: Friday, January 27, 1984

Docket Number:

Place of Proceeding: 1717 "H" Street, N. W.
Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the files of the Commission.

Marilynn M. Nations
Official Reporter (Typed)

Marilynn M. Nations
Official Reporter (Signature)

'84 AGO 28 A10:13

STATEMENT OF DR. THEODORE B. TAYLOR

Before the Nuclear Regulatory Commission
Regarding the Need to Convert Domestic Research Reactors
From Highly Enriched to Low-Enriched Uranium Fuels
January 27, 1984

From 1949 to 1956 I worked on the design of nuclear explosives at the Los Alamos Scientific Laboratory. From 1956 to 1964 I worked at the General Atomic Division of General Dynamics Corporation, during which period I helped design the TRIGA research reactor. From 1964 to 1966 I was Deputy Director (Scientific) of the Defense Atomic Support Agency in Washington. The following years have been spent as an independent consultant to the U.S. Atomic Energy Commission and a number of other organizations, working on nuclear safeguards issues and other energy-related matters. I served on the Presidential Commission on the Accident at Three Mile Island. I am co-author of Nuclear Theft: Risks and Safeguards, as well as a number of other books and articles dealing with nuclear safeguards and related subjects. This morning I appear as a member of the Board of Directors of Nuclear Control Institute. A more detailed statement of my professional qualifications is attached.

It is my opinion that all domestic research reactors under the licensing authority of the Nuclear Regulatory Commission should be required to convert from highly enriched uranium (HEU) to low-enriched uranium (LEU) fuels as soon as the LEU fuels are available. I know of no reason that could justify the unique safeguards risks associated with continued operation of these reactors with materials so internationally dangerous. I come to this conclusion as a former designer of both nuclear weapons and research reactors, and from extensive involvement in the field of nuclear safeguards. The basis for this conclusion is as follows:

Weapons Implications

Uranium enriched to 93% in the isotope ^{235}U is weapons-grade. It is weapons-grade because it is directly usable in nuclear weapons without any further isotopic enrichment. Because it is weapons-grade material, 93% enriched uranium is a potentially attractive target for theft or diversion by terrorist groups or nations intent on acquiring nuclear weapons. The potential consequences of such theft or diversion are very grave.

A group or nation capable of making nuclear weapons from 93% enriched uranium would not have any significant difficulty in separating the uranium from the uranium-aluminum eutectic in which it is found in flat-plate MTR-type research reactor fuel. The methods for doing that are widely published and fairly straightforward.[2]

Such a national or subnational group also would not have substantial difficulty in removing the uranium from MTR-type research reactor fuel that had been irradiated sporadically in a low-power reactor (e.g., a few hours per week at a maximum power of 100 kw_{th}.) It is more difficult than separating the uranium from unirradiated fuel plates, but it is something that could be done with techniques that are widely published. If the safety rules are compatible with a high degree of military urgency to obtain the uranium for weapons purposes, then the fact that the fuel contained some fission products would not get in the way very much.

Furthermore, the fact that some of the HEU at research reactors might be in the form of irradiated fuel, either in the core or in storage holes, while other material was in the form of fresh fuel in separate storage, would be little if any deterrent to theft of all the material. Dose rates far in excess of what most NRC-licensed research reactors appear capable of routinely producing in their fuel bundles would be necessary, in my opinion, for the fuel to be "self-protecting." To cite one specific example, if the calculations in Dr. Roger Kohn's September 4, 1982, declaration in the UCLA licensing case are correct, fuel bundles in the UCLA reactor drop below 100 rem/hour (at three feet from any accessible surface without intervening shielding) after just 8 hours of shutdown, below 34 rem/hour after one day, and apparently down to a few rem per hour after a shutdown or storage period of a few weeks. If correct, and assuming that the reactor operates only a few hours per week, neither irradiated fuel in storage nor in the core would be self-protecting and would be little deterrent to dedicated individuals or groups intent on acquiring nuclear weapons material.

To assert that the 4000 to 5000 grams of uranium-235 at 93% enrichment in the form of uranium-aluminum flat plate fuel, which are authorized at this and seven other university research reactors, would be of no interest to someone intent on manufacturing a nuclear weapon would be simply incorrect. It is, in my opinion, a credible threat that people might break into such research reactor facilities in order to acquire HEU. Particularly if one supposes a blackmarket and people selling stolen HEU at, say, a hundred thousand dollars per kilo. At present, only three NRC-licensed university reactors are authorized to store less than four to five kilograms of uranium-235 in highly enriched fuels, while 12 are authorized to store larger amounts ranging up to 45 kilograms U-235.

It is my opinion that anything more than a kilogram would be clearly excessive. From a proliferation standpoint there should be a significant burden upon a university to demonstrate that it could not perform the functions for which the reactor was intended without the requested highly enriched uranium. I would say that even more broadly: highly enriched uranium should not be used in quantities of more than a few hundred grams under any circumstances unless there is an absolutely compelling reason to do so. I know of no such reason that would be relevant to these reactors.

It is my opinion that the enrichment of these fuels is excessive. For general research use, the only advantage in going from 20% enriched uranium to 93% enriched uranium is that the neutron flux may increase somewhat at the same power level. I don't know what that increase in flux is for each specific reactor, but it is very hard to imagine that it would change significantly the nature of the experimental programs if the enrichment were reduced. Everybody wants to have all the neutrons they can get, but the universities already have limited themselves, by limiting the power of their reactors, and if they wanted more neutron flux they might increase the power level --- from 100 to 120 kilowatts, for example. One is talking about not anywhere near doubling the flux by increasing the enrichment.

Small kilogram quantities of uranium-235 in 93% enriched form would have, by far, greater potential consequences if stolen than an equal or even somewhat larger amount of uranium-235 in 20% enriched fuel. The critical mass of fully enriched uranium in metallic form with an ordinary reflector is roughly 20 kilograms. It depends on what the reflector is. With a more efficient reflector, the critical mass is considerably less. For example, critical mass with a thick reflector made of beryllium is approximately 11 kg. of uranium-235.

These figures are for the critical mass of uranium-235 at normal density. When compressed, the critical mass is considerably less. As I wrote in Nuclear Theft: Risks and Safeguards (Ballinger, Cambridge, Mass., 1974, at p. 20): "If, on the other hand the material is to be used in an implosion type of fission bomb, the amount required may be significantly lower than these quantities. Materials that are compressed above their normal densities have a lower critical mass than when they are uncompressed. In the special case when both the core and the reflector are compressed by the same factor, the critical mass is reduced by the square of that factor. Thus, when a spherical core and reflector assembly that is initially close to one critical mass is compressed to twice its initial density, it will correspond to about four critical masses." The maximum compression achievable in an implosion type fission weapon, and thus the minimum amount of uranium necessary to make such a weapon, depends upon the knowledge, skill, equipment and facilities of the bomb maker.

For 20% enriched uranium in metallic form with an ordinary reflector, the normal density critical mass of contained uranium-

235 rises to over 50 kg. It is possible to make a nuclear explosive with 20% enriched uranium but it would be very heavy, very inefficient and difficult to handle because of the relatively large amount of non-fissionable uranium 238 contained in this fuel. You would need approximately three times as much uranium-235 in the 20% enriched form as you would in the 93% enriched form in order to make a critical mass, but more important is the fact that you would be dealing with (three times five or) fifteen times as much uranium, which is much harder to move, much harder to compress.

Threats

The potential consequences of the theft of a single kilogram of 93% enriched uranium would be considerable if someone simply needed one kilogram to supplement an amount already obtained or if they needed or wanted some highly enriched uranium to make a threatened authority take a blackmail threat more seriously. To send a few grams would be so relatively easy to do that it might not have much effect on the credibility of the threat. To send a kilogram begins to be quite significant and they can simply say, "We haven't sent you more because, as you know, that is a significant fraction of the total amount we would need. We just want you to know we have kilogram quantities of this material and here is a kilogram."

Therefore, in my view, a request by an institution for kilogram quantities of highly enriched uranium is excessive unless there is some overriding reason that I cannot imagine --- such as national defense research, and even then I know of no such research which would require HEU fuel for such a reactor.

There is no crucial research at university reactors of which I am aware that would require weapons-grade uranium. I would say, in fact, that for uses of any kind, any quantity of HEU would be excessive. I say that because even in gram quantities there should be a special reason to have it because gram quantities could still be extremely helpful to people making a threat that might not necessarily be a hoax. It just reduces the amount of material they need in order to make a bomb, and also establishes credibility for a threat.

I have been informed that the original Argonaut reactor operated on 20% enriched fuel and that a number of other Argonauts have likewise operated on 20% enriched fuel. Assuming that is correct, I know of no reason --- and find it hard to imagine one --- why all Argonaut reactors should not likewise operate on 20% enriched uranium. I have also been informed that the University of Florida's Argonaut reactor was to be involved in testing some 4.8% enriched uranium oxide fuel. Assuming that that also is correct, that kind of fuel would likewise seem to me as something worth pursuing for other Argonaut reactors because it is even further away from weapons material.

I also have been informed that General Atomic currently has available low-enriched TRIGA fuel not only for conversion of TRIGA reactors, but for conversion of Argonaut and other research reactors presently utilizing highly enriched MTR-type plate fuel. If necessary, I would view conversion of these non-TRIGA reactors to low-enriched TRIGA fuel as a favorable alternative to permitting their continued operation with highly enriched uranium. It is much more difficult to make weapons of any kind out of lower enrichment uranium; the compromises in neutron flux, which I think are the main concern, are not large, if present at all.

Safety

Besides significant safeguards advantages in making a conversion to low-enriched TRIGA fuel, there also would be significant safety benefits. There certainly was a major safety benefit in the TRIGA fuel when we designed it and the TRIGA reactor.[3] The main feature was a very strong prompt negative temperature coefficient, much higher than other research reactors, which meant that even if it went prompt critical the rise in temperature would extremely rapidly stop the chain reaction. That still stands. There is, of course, a level of excess reactivity above which the safety feature of not being able to damage any of the fuel with an accidental excursion is no longer true. You can always make it over-critical by design, to make it not have that self-limiting feature, but I don't see any excuse for doing it with any medium power research reactor, up to a megawatt at least.

The level of excess reactivity at which the prompt negative temperature coefficient ceases to be an effective self-limiting feature would be much higher for a TRIGA reactor or a reactor with TRIGA fuel than for the Argonaut and other research reactors operating with MTR-type fuel. At comparable levels of excess reactivity, the TRIGA fuel would definitely have significant safety advantages.

The difference in the TRIGA fuel is due to the fact that when the ratio of captures (in the water and other materials) to fissions (in the fuel) goes up, the reactivity goes down. That effect is produced by a change in temperature in the fuel itself, relative to the cooling water, and thus requires no heat conduction. It happens instantaneously because the heat is liberated by the fission reaction right in the fuel. In MTR-type research reactors the heat has to be transferred to the water, which takes a while, to make it expand. It is the expansion of that water plus some other effects that have to do with the water having to heat up that makes the reactivity go down. Because of this time-delay involved with the transfer of heat from the fuel meat to the water in MTR-type reactors, the shutdown mechanism is slower, permitting greater energy release before shutdown for an excursion of the same exponential period and a greater opportunity for fuel melting to occur before the excursion terminates than is true with the TRIGA.

That shutdown mechanism in the MTR-type reactors, requiring transfer of the heat to the water to cancel the reactivity, can produce effects in the water like boiling or a sudden expansion of the coolant which can, in effect, do some damage, even if fuel melting does not occur. The likelihood of there being changes in the fuel arrangement or in the grid supports or whatever is less for the TRIGA than for the Argonaut, according to the comparative designs when I knew about them. I was familiar with the Argonaut design at the time we designed the TRIGA.

In addition to the TRIGA fuel having a negative temperature coefficient that is far more prompt (i.e., it comes into play much faster), the size of the negative coefficient is also far larger, so the excursion is terminated much sooner, providing substantial additional protection against fuel melting.

The conversion to lower enriched uranium fuel, be it TRIGA fuel or flat plate fuel, would likely increase the negative temperature coefficient because of another factor, the Doppler effect. I cannot be absolutely sure there are not some compensating factors, but the Doppler broadening coefficient contribution to the temperature coefficient will go up and I do not know of any reason why other things would happen to make it go down.

A reduction in enrichment of the fuel can thus decrease the possibility or consequences of a destructive power excursion or criticality accident. Low enriched fuel has a contribution to limiting an excursion, an abating effect, that is the cancelling out of the reactivity because of the increased capturing by uranium-238. I cannot make the blanket statement that for any reactor design that it would be safer; it would be dependent upon a given change in the reactivity.

Security

Regarding what kind of security would be sufficient to satisfactorily minimize the risk of theft or diversion of kilogram quantities of HEU, consistent with the potential consequences of its theft, I would say that it should not be possible for a group quite knowledgeable about security and how to defeat it to describe to a jury of experts a credible scenario for stealing the material. In other words, I am thinking in terms of a jury situation, and I would say that security would be adequate if, and only if, such a jury of experts could not be presented with a theft plan that they thought had a reasonable chance of working.

I also would stress that an almost exclusive reliance on intrusion alarms tied into a campus police station absolutely would not be adequate, in my view, because that does not say anything about the ability of the campus police to effectively intercept people carrying out the theft. However, if there were an intrusion alarm between the point of entry and the material, and physical barriers in between sufficient to prevent penetration until the campus police and an additional response force had arrived on the scene, then I would say that would be effective. But by definition I am saying that something considerably more than an intrusion alarm is required --- that is, barriers, very heavy containers or the equivalent, something that would create a physical delay of some significance, to ensure getting protective people there. And when I say protective people, I do not mean simply one or two watchmen checking in, but a force capable of successfullly preventing the theft.

Any contention that detection of the theft or post-theft reporting woulk be sufficient is, in my opinion, highly irresponsible and not at all consistent with the potentially very significant consequences of theft of kilogram quantities of HEU. Merely being able to detect and report theft, while failing to adequately protect against theft, would be unconscionable.

I would view a theft of a kilogram or more of uranium-235 at 93% enrichment as having extremely significant potential consequences, simply by virtue of it being stolen. By this I mean it is then no longer a hypothetical question. When it has actually happened, it means that some people have gone to the trouble to steal that material. Having done so, it could be entering the black market, it could be joined with other materials which are on the blackmarket, it could go in the direction of being the start of the construction of weapons. I would say that if I heard a kilogram or more of highly enriched uranium had been stolen, I'd be extremely concerned. That would have international implications of great importance.

Conclusion

In conclusion, I would say continued use of highly enriched uranium in quantities of more than a few grams at domestic research reactors is highly undesirable and dangerous. The burden of proof should be on the reactor operators to make clear why it is truly necessary to use HEU as opposed to using 20% or less enriched uranium. I have not seen that case made. The essential consideration for the Nuclear Regulatory Commission is that highly enriched uranium is not essential to the operation of these reactors but is an essential ingredient for making nuclear weapons. The hazards of nuclear weapons being produced do not disappear even if the quantities of HEU at individual sites are not sufficient to make one nuclear weapon because these sources could be pooled.

It is very important for the Commissioners, in order to make rational decisions about the consequences of theft of uranium-235, to know what are the minimum quantities of uranium-235 necessary to make a nuclear weapon. I can say flatly that I would be very concerned about theft, clear evidence of theft, of a kilogram or more of highly enriched uranium, and I think everyone should be. If you ask how much less than a kilogram, I really could not go into that, and I want to make sure I am not being taken to say that one kilogram of highly enriched uranium is the minimum quantity necessary to make a bomb. That minimum quantity is not a well defined number at all. It depends on the talents, experience and requirements of the designers.

From the point of view of one who has designed nuclear weapons, a kilogram or more of 93% enriched uranium is certainly a significant quantity. There is no question about that. It should not be around in situations where theft could occur unless there is some vast overriding reason such as national defense, and I know of no such reason which could be remotely applicable to the reactors licensed by the NRC.

It is my opinion that HEU should be prohibited internationally. We have the mechanisms set up in the United States to work toward that objective. HEU should be prohibited except under conditions that I would say are extraordinary. The prohibition should come first and the exception should come later. No research facility should have a quantity of HEU sufficient for building a weapon under any circumstances for any purpose.

I note that the NRC, on August 24, 1982, issued a statement of policy committing itself to exercising its licensing authority to reduce, "to the maximum extent possible," the use of HEU in domestic and foreign research reactors (47 FR 37007). It appears to me very important that the NRC carry out that policy with regard to all research reactors and HEU under its direct control in order to set a domestic example that foreign regulators and operators of research reactors can follow. Such leadership by the Commission can also influence the policy and actions of the U.S. Department of Energy with regard to the far greater number of research reactors and far larger quantities of civilian HEU under its control.

Therefore, given what I know about what HEU can be used for in terms of construction of a nuclear weapon or making of a nuclear threat, and also based on what I know about the needs of research reactors, the Commission should promptly issue a rule requiring the use of fuel of a lower enrichment. I would say further that every institution now using research reactors should look very carefully at the risks versus the benefits obtained (and the risks are significant) and treat them as potentially very dangerous pieces of equipment. The danger is especially worrisome when there are kilogram or more quantities of nuclear materials from which nuclear weapons can be made. The whole institution, not merely the nuclear engineering department, should make that assessment. My advice for them would be to avoid having reactors unless you absolutely have to. If you must have a reactor, always use the lower enrichment and keep the lowest quantity of uranium on hand. I doubt that there is any crucial research at a university requiring weapons-grade uranium.

FOOTNOTES

1. See also my declaration dated December 16, 1982, before the Atomic Safety and Licensing Board considering the license-renewal application of the UCLA Argonaut research reactor (Docket No. 50-142).

2. One such simple method is described on page 97 of John McPhee's The Curve of Binding Energy, Random House, NY, 1973, 1974.

3. A good description of the origins, intent, and basic operating principles of the TRIGA and its fuel can be found in Freeman Dyson's Disturbing the Universe (Harper & Row, NY, 1979), pgs. 94-102.

Professional Qualifications

DR. THEODORE B. TAYLOR

My name is Theodore B. Taylor. I am Chairman of the Board of Nova, Inc., a technical consulting firm specializing in energy applications.

I received my B.S. degree in physics in 1945 from the California Institute of Technology and my Ph.D. degree in theoretical physics from Cornell University in 1954.

From 1946 to 1949 I worked as a theoretical physicist at the University of California Radiation Laboratory in Berkeley.

From 1949 to 1956 I was on the staff of the Los Alamos Scientific Laboratory, working on the design of nuclear explosives. One of my primary assignments at Los Alamos was to design fission bombs of very small physical dimensions and mass.

In 1956 I joined the General Atomic Division of General Dynamics Corporation where, along with Edward Teller, Freeman Dyson, and others, I helped design the TRIGA research reactor. While at General Atomic I was also technical director of the Nuclear Space Propulsion Project (Project Orion).

From 1964 to 1966 I was deputy director (scientific) of the Defense Atomic Support Agency, U.S. Department of Defense.

I spent the following two years in Vienna, Austria, as an independent consultant to the U.S. Atomic Energy Commission and several other organizations, working on the subject of international safeguards for nuclear materials.

In 1967 I founded the International Research and Technology Corporation, a company primarily concerned with studies of the impact of technology on society, which I served as Chairman of the Board until 1976.

From 1976 to 1980 I was Visiting Lecturer with rank of Professor in the Mechanical and Aerospace Engineering Department at Princeton University.

In the aftermath of the accident at the Three Mile Island nuclear power plant, I served as a Commissioner on the President's Commission on the Accident at Three Mile Island (the "Kemeny Commission.")

I am a member of the American Association for the Advancement of Science and the American Physical Society, a member

of the Board of Directors of Nuclear Control Institute, and have served as a consultant to the Air Force Science Advisory Board, 1955-58, Los Alamos Scientific Laboratory, 1956-64, Aerospace Corporation, 1960-61, Atomic Energy Commission, 1966-70, Defense Atomic Support Agency, 1966-69, Rockefeller Foundation 1977-79, and was chairman of the Los Alamos Study Group, Air Force Space Study Commission, 1961.

In 1965 I was one of the recipients of the Ernest C. Lawrence Memorial Award of the AEC for work on the development of nuclear explosives and the TRIGA research reactor.

I am co-author of The Restoration of The Earth (1973), Nuclear Theft: Risks and Safeguards (1974), Energy: The Next Twenty Years (1979), and author of numerous articles on nuclear safeguards and proliferation in technical journals and popular media. A more detailed account of my activities in the safeguards field can be found in John McPhee's book, The Curve of Binding Energy (1973, 1974).

I maintain an active "Q" clearance.

Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

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STATEMENT OF PAUL L. LEVENTHAL

Before The Nuclear Regulatory Commission
Regarding the Need to Convert Domestic Research Reactors
From Highly Enriched to Low-Enriched Uranium Fuels
January 27, 1984

I appreciate the decision of the Commission to have the additional series of meetings being held today to consider the non-proliferation policy and security implications of a domestic rule on converting research reactors from highly enriched to low-enriched uranium fuels. Thank you for the opportunity to appear at this public session.

I am Paul Leventhal, President of Nuclear Control Institute, a non-profit, educational organization concerned with the dangers of nuclear-weapons proliferation. In 1972-1976, I was Special Counsel to the Senate Government Operations Committee where I had responsibility for investigations, hearings and drafting legislation leading to enactment of the Energy Reorganization Act of 1974 and the Nuclear Non-Proliferation Act of 1978. In 1978-1980, I was Staff Director of the Senate Nuclear Regulation Subcommittee, in which capacity I was also Co-Director of the Special Senate Investigation of the Three Mile Island Nuclear Accident. I am accompanied by John Buell, Issues Director of Nuclear Control Institute, who assisted in the preparation of this statement.

Also with me today is by David Albright, Research Associate of the Federation of American Scientists, who has prepared data referred to in this statement and who is submitting to the Commission a letter from him and Dr. Frank von Hippel, Chairman of FAS, and an additional report on the reduced enrichment program.

There are many technically complex and politically difficult issues to contend with in seeking to prevent the proliferation of nuclear weapons, but the use of highly enriched, weapons-grade uranium as fuel for civilian research reactors stands out as one problem that can be solved with relative ease.

In contrast to the seemingly insurmountable technological barriers to achieving effective controls on some sensitive nuclear materials and technologies, the Reduced Enrichment Research and Test Reactor (RERTR) Program provides a readily achievable

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solution. Although many U.S. non-proliferation initiatives meet with stiff political resistance abroad, the U.S. objective of phasing out exports of HEU in conjunction with cooperative efforts to convert research reactors to LEU has been received surprisingly well by foreign governments.

There is however, a major potential obstacle to achieving this important non-proliferation objective. If the United States fails to practice at home what we preach abroad, the implicit message will not be lost on the nations we are trying to influence to eliminate highly enriched uranium from their research reactor programs.

The Commission is to be commended for the leadership role it played on August 24, 1982 by issuing a policy statement (47 FR 3006-3007) announcing its interest "in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors." The statement closed with the following significant observation and commitment:

> The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. research reactor operators.

Given the Commission's forthright acknowledgement of the linkage between domestic and foreign conversion of researach reactors to lower enriched fuel, the Commission's development of a proposed domestic rule on this question is certain to have profound international implications. We would urge, therefore, that all domestic research reactors under the Commission's authority be required to convert to low-enriched uranium as soon as such fuel is available.

Such an unambiguous rule would have the effect not only of encouraging the conversion of foreign reactors that now require reloads of HEU, but would set an example for the conversion of smaller reactors that have a lifetime supply of fuel on site. Dr. Taylor has made clear that the existence of even kilogram quantities of HEU, whether irradiated or not, presents an unacceptable risk of theft in civilian research programs.

A strong domestic rule by the Commission can also serve to bolster the sometimes lagging support for the RERTR Program within the Administration and to encourage the Department of Energy to begin conversion of its research reactors to LEU.

The security and non-proliferation stakes are quite high.

There are currently 137 research and test reactors in 34 countries which use HEU as fuel. More than a third of these reactors (45) are in the United States. According to data assembled by the RERTR Program, the annual requirement of U-235 for these reactors is 1,046 kilograms of which the U.S. provides 1,030 kilograms, or 99 percent. There are 4,100 kilograms of U-235 in circulation at any one time — enough for at least 205 atomic bombs on the basis of a conservative estimate of 20 kilograms per weapon.

According to data assembled by David Albright of FAS, the United States has exported some 23,590 kilograms of highly enriched uranium (containing 16,980 kilograms of U-235) to 43 nations from the start of the Atoms for Peace program through 1982. The bar graph showing annual exports indicates there were a number of years when exports of HEU exceeded the annual foreign requirement of about 500 kilograms of U-235. Apparently, in those years, the United States was supplying lifetime cores to the 37 low-powered research reactors that have little or no reload requirements.

Since the mid-1970s there is a growing consensus that the use of HEU in civilian research programs presents an unwarranted proliferation risk and should be discontinued in view of the feasibility of converting to lower enriched fuel. The summary report of the International Fuel Cycle Evaluation (INFCE, 1980) stated that it is feasible to markedly reduce the enrichment of a great majority of research reactors and endorsed the conversion of HEU-fueled research reactors to lower enrichment.

In 1977, the United States announced a nuclear non-proliferation initiative to significantly reduce U.S.-supplied inventories of HEU for fueling research reactors and announced plans for the RERTR Program to develop a low enriched (20% U-235 or less) alternative fuels. The RERTR Program generally has functioned well since 1978 and already has developed LEU fuels suitable for most of the research reactors in the world.

This success has come despite less than enthusiastic support from certain quarters within the Department of Energy, the lead agency for the program. The GAO has reported that in 1981, DOE requested only $1 million for the program -- one fifth of the previous years funding. Eventually another $1.6 million was raised from other programs in DOE, State and ACDA, but that still left funding at half of what it had been the previous year. Since that time, funding has been gradually increased, but it has taken three years to reach levels set by the previous Administration. Even now there are signs of a continuing struggle by proponents of the program to gain adequate funding.

The potential of a strong, comprehensive rule by the Commission influencing the direction of Energy Department's own research reactor program should not be overlooked. Currently, NRC-licensed research reactors account for only ten percent of the annual civilian domestic HEU requirement. The other 90 percent is used by the 15 non-defense reactors operated by DOE. According to data developed by the RERTR Program, all but one of these reactors could convert to the LEU fuel now being developed. Even the remaining reactor, the ATR in Idaho, can be converted if it is decided that the reduction in performance characteristics is an acceptable price to pay for eliminating the use of HEU from the research reactor program.

Although foreign support of the RERTR Program has been encouraging, there remains the outstanding issue of whether the United States will take the lead by moving promptly toward LEU conversion. As recently as last November at the RERTR annual meeting in Japan, the issue of "even handedness" by the United States was raised at a roundtable discussion. Commissioner Gilinsky assured the participants that the Commission "intends to demonstrate that conversion to low enriched fuel is not a difficult process by taking steps to enable domestic reactors operating in the United States to convert to low enriched fuels," and he cited the proposed rulemaking that is the subject of today's meeting.

The Commission should set an example by promulgating a rule that requires conversion not only of the university reactors under its jurisdiction, but the NRC-licensed government and industry reactors as well: the National Bureau of Standards Reactor, the Union Carbide Reactor, the General Atomic Triga-F Reactor, the Westinghouse Nuclear Training Reactor, the General Electric Test Reactor, and the General Electric Nuclear Training Reactor.

The conversion of university reactors to LEU fuel provides the additional benefit of eliminating the need for severe security measures that are not appropriate to institutions of learning. As noted by Dr. Taylor, such security measures are needed at any facility using even kilogram quantities of this material. In fact, such security measures are generally not instituted (as is outlined in Mr. Hirsch's testimony) due to their being antithetical to a university environment. Conversion to LEU is the easiest solution to this problem.

Finally, if highly enriched uranium were no longer required to fuel civilian research reactors, and if no further production of HEU is required for the weapons stockpile or for naval propulsion fuel, as may well to be the case, the basis would be established for suspending further production of HEU and even for blending down existing HEU stocks into low enriched uranium for use in civilian research and power programs.

Testimony by Daniel Hirsch
Committee to Bridge the Gap

before the Nuclear Regulatory Commission
Jan. 27, 1984

My name is Daniel Hirsch. I am President of the Committee to Bridge the Gap, a public interest organization concerned with the safety and security of research reactors across the country. I am also a member of the Executive Committee of the Southern California Federation of Scientists, a 3-year-old organization of scientists and engineers concerned with nuclear non-proliferation matters. I am Visiting Lecturer at the University of California, teaching energy policy and nuclear non-proliferation policy. And I am Director of the Adlai Stevenson Program on Nuclear Policy at UC Santa Cruz.

My remarks today before you summarize the results of a two-year study by members of the Committee to Bridge the Gap and the Southern California Federation of Scientists regarding the need to convert research reactors from weapons-grade nuclear materials and the technical feasibility thereof. This study has included review of the situation in this regard at a number of research reactors around the country. In my comments and in the longer report being provided as background it should be stressed that we reviewed many research reactors and the conclusions are generic in nature. Specific instances are not identified by specific reactor to which they apply for obvious security reasons. They are selected from review of records relating to about a third of the reactors using highly enriched uranium.

Of the security risks associated with research reactors, the threat of theft of weapons-grade nuclear material by someone intent on acquiring a clandestine fission explosive is essentially unique to this kind of reactor. This is because many research reactors utilize uranium that is approximately thirty times the enrichment of the fuel at commercial power reactors. Unlike the fuel at power reactors, therefore, it is directly useable, if stolen or diverted, in a nuclear weapon.

The fact that the fuel is generally in the form of aluminum alloy plates is little or no barrier for such weapons use. The methods of extraction are essentially Chem I level; I have described several such methods in my longer report to you. The aluminum cladding and alloy thus are little more than gift-wrapping for bomb material.

The unique security risk associated with research reactor fuels is exacerbated by the unique environment in which they are often located. Many of these reactors are located on university campuses where stringent security measures necessary to adequately protect such uniquely sensitive materials are perceived to conflict with the open atmosphere generally associated with such institutions.

Security at these facilities is often extraordinarily lax. Weapons-grade uranium, the theft of which could have very serious international implications, is often protected at a similar level of security on these campuses as personnel records or the student store. The principal and often solitary security precaution is a readily bypassed alarm system tied into the campus police office. One NRC inspection of an east coast research reactor found that on occasion there was only one campus police officer available to respond to an alarm, that he had no instructions what to do once he got there nor upon whom to call for assistance if needed. In another case, a reactor facility had so many false alarms that it had tuned down its detection devices to such an extent that an NRC inspector was unable to set off the alarm despite walking around in the reactor room for a considerable period of time with the alarm system armed.

One research reactor, built twenty years ago when the campus wished to make the reactor a "showplace", was built with all walls and doors made out of glass. Years later an NRC inspector found the situation to pose very serious security problems, as the glass obviously provided essentially no barrier to entry.

At numerous facilities, keys have been lost or duplicated without authorization, people with keys have left the university, and nonetheless the reactor facility has not been rekeyed. In one case an inspector found the key to the reactor unattended in the reactor console, available for anyone to take. In another case, three master keys were lost, without rekeying of the facility for years.

Locks at the facilities are extremely poor. One inspector noted "The inspector demonstrated to licensee staff that the door ... could be opened using a small screwdriver." Numerous locking mechanisms were found to be inoperable; despite commitments by licensee personnel to correct the problem, a year later on another inspection the same problems remained.

At one facility entry to the facility was observed to require only knocking on an outside door and having it opened by students inside. At another facility, the doors were built with the hinges facing out, so picking the lock wasn't even necessary--the door could just be taken off the hinges.

Doors have on numerous occasions at most of these facilities found to be left unlocked.

The equipment necessary for removing the nuclear material is all readily available at the facility itself, including the electronic equipment necessary for passing a loop around the intrusion alarm system and mimicking any line supervision that might exist. Fuel removal tools used for normal fuel removal as just as readily available for unauthorized use; with alarm system bypassed, a thief could have hours to undertake removal, whereas a study by Los Alamost said 1.25 hours would be sufficient for theft at most research reactors.

Most of these reactors cannot sustain anywhere near 100 Rem/hour radiation dose per fuel element. At an average research reactor, dose rate goes below that level after a shutdown of just 8 hours; down to 11 Rem/hour in a week. Since these reactors often operate only a few hours per week, the likely dose to members of a group stealing material would be less than that permitted radiation workers under the regulations.

Sometimes the storage area for the fresh fuel is described as a "vault" and the storage container as a "safe." The "vaults" are almost always simply a room with a door, often used for other storage; in one case, the door is a simple chain link fence door.

In more than one facility, the "safe" is merely a filing cabinet.

In short, the security found at these university reactor labs is the kind one would expect for labs at a university: alarm systems tied into a campus police office, scores of keys given out to students, staff,and faculty, and minimal thought as to what to do if there really were a determined effort to remove fuel from the facility. There is, judging from our review, a failure to perceive the risks associated with theft or diversion of the weapons-grade materials they possess.

A conversation I had with one individual in charge of security at such a reactor is a good case in point. He is a former student who stayed on at the facility after graduating and, as is often the case, in addition to his reactor operator duties was assigned security responsibilities. He told me not to worry about security problems at research reactors like his because if someone stole the fuel, the FBI would, he asserted, eventually catch the thieves and even if not, "it's real hard to make a bomb." Listening to him during this conversation was a friend of his who works at a nearby defense plant. He disagreed, saying the construction of a fission device was relatively simple, that he could do it with equipment he had access to if he had the uranium. To which the security official, jokingly one must presume, replied as he pointed to the keys on his belt, that he had the key to some 93% enriched stuff.

Neither of those two individuals had the motivation to build such a weapon. But it is sobering to think that one man with a key and one or more people with a metal lathe and some conventional explosives expertise and some nuclear background could provide very considerable instability in the international sphere and considerable destruction on the human level.

A more likely threat is a group desiring to construct such a weapon target a university reactor for theft because of the presence of HEU and the relatively lax security.

Furthermore, we can't expect other nations to convert if we fail to do so ourselves.

Which brings me to the recommendations by the research reactor operators regarding your August 1982 Policy on HEU Use at Research Reactors. In 1982 you committed the agency to "the maximum extent possible" convert domestic and foreign reactors to low enriched fuels that cannot be used for weapons purposes if stolen or diverted. The research reactor community, through a report by an LEU Study Group, recommends that you essentially implement that Policy by exempting all but a handful of their reactors from conversion. This is very dangerous. Furthermore, the arguments advanced on their behalf significantly overstate the conversion barriers and understate the advantages.

The report defines "technical feasibility" with regards conversion as anything costing more than a few thousand dollars--a unique definition. It goes on to admit, however, that there are no technical barriers to the conversion of any but perhaps two of the university reactors. Yet it argues the rest should not be converted.

It asserts it would cost $600,000 per reactor to convert--$350,000 for fuel and $250,000 for safety analysis costs. These are wildly inflated figures. Fuel would be more like $150,000 ($500/plate), safety analysis costs just a few thousand. RERTR is to make the basic safety determinations about these fuels; all that conversion involves really is pulling HEU fuel and putting in LEU. Far more major alterations of these reactors have been made with nowhere near the expenditure on safety analyses that are being claimed. Thus, converting all university reactors would cost perhaps $5 million, not the $15 million claimed by the operators.

However, even were the $15 million figure correct, it is a very small price to pay for eliminating weapons-grade uranium from all university research reactors. Theft from even one location would have consequences that would make that dollar figure pale in comparison. And given the $50 million to be spent by RERTR in researching and developing these fuels, spending a few million to actually convert reactors (and keep alive the possibility of convincing foreign operators to convert) is well worth the money.

The research reactor operators who received the NRC $60,000 contract to do the LEU Study Group Report--which raises serious questions, it must be added, by having people representing the licensees under threat of regulation to perform, at NRC expense, the review of whether the Policy should be implemented--also argued conversion could take up to 120 months at reactors. This is extraordinary--conversions have been done numerous times already to date, involving very little time. One simply pulls HEU out and reloads with LEU; little more than that is required frankly, and the licensees are making a big thing out of a small inconvenience. The cost benefit relationship is threat of acquisition of a clandestine fission explosive on the one hand and some minor inconvenience on the other.

The proposal by the licensees--that "lifetime" cores be exempted--means basically that they are requesting that your Policy be gutted. Their definition of "lifetime" core--that the facility can probably operate with the fuel in the core, in storage, or on order--means essentially that HEU will be present and available for theft for the entire lifetime of the reactor. This is precisely what the Commission's Policy is designed to prevent.

The research reactor representatives who wrote the LEU Study Group report also downplayed the significant safety advantages of LEU fuel. In particular, the Doppler effect due to the increased U-238 means much greater protection from the primary safety hazard generally associated with research reactors--destructive power excursions of the kind that demolished the SL-1 (HEU plate-type) reactor twenty years ago. Furthermore, if an oxide or TRIGA LEU were used (and TRIGA LEU can be used to convert plate type reactors, and has been successfully numerous times), additional safety advantages would be obtained due to the very low melting temperature of the aluminum fuel used in these HEU reactors presently.

Either security must be significantly upgraded at these facilities--which would disrupt the open atmosphere and be very costly--or the HEU should be removed and LEU replace it.

This is one of the few issues for which there is a sweet technical fix. The research reactors can do all they now do, with fuel that if stolen is not useful for an atomic weapon.

The Commission has taken an important step in its August 1982 Policy pledging to convert research reactors to the maximum extent possible to non-weapons-grade fuel. There are no technical barriers anymore to such conversion. I applaud the Commission Policy and in most strong terms urge you to "stick to your guns" and carry out the Policy you have agreed to and which has gained such widespread international support. Thank you.

WEAPONS-GRADE URANIUM ON CAMPUS

The Need to Convert Research Reactors to Lower Enrichment Fuels

A Report to the NRC Commissioners
by Daniel Hirsch
January 27, 1984

ACKNOWLEDGMENTS

This report was based on research into the generic question of conversion of research reactors to non-weapons-grade fuels conducted by a joint taskforce of the Committee to Bridge the Gap, a public interest organization concerned with safety and non-proliferation matters related to the nation's research reactors, and the Southern California Federation of Scientists, an organization of engineers and scientists concerned with nuclear power and nuclear weapons issues.

The report included review of material in the public docket of nearly a third of the reactors using highly enriched uranium in this country, as well as materials obtained under the Freedom of Information Act.

Special thanks to the following for input on various aspects of this study: Dr. James Warf, Professor of Chemistry at USC and member of SCFS, on the chemistry of uranium extraction from research reactor fuel; Dr. James Lewis, Chemistry Department, University of California at Santa Cruz, in the same matter; Steven Aftergood, Southern California Federation of Scientists, for review of past conversions of research reactors and LEU availability; Dr. Roger Kohn, physicist associated with CBG, dose rate calculations for irradiated fuel; Boyd Norton, formerly reactor physicist with the AEC's Special Power Excursion Reactor Test program (SPERT),on safety advantages to LEU fuels.

Gratitude is expressed also to the inputs of information and viewpoint presented by Dr. Theodore Taylor, Dr. Herbert Scoville, and Dr. David Hafemeister.

Responsibility for the contents of this reports rests exclusively, however, with its author, Daniel Hirsch; Visiting Lecturer at the University of California, teaching energy policy and nuclear non-proliferation policy; Director of the Adlai Stevenson Program on Nuclear Policy at UCSC; President of the Committee to Bridge the Gap and a member of the Executive Committee of the Southern California Federation of Scientists.

WEAPONS-GRADE URANIUM ON CAMPUS

The Need to Convert Research Reactors to Lower Enrichment Fuels

The Unique Risk Associated With Non-Power Reactors

Of the security risks associated with research and test reactors--the necessity to protect against acts of radiological sabotage and, for those reactors utilizing highly enriched uranium as fuel, to protect also against theft of that material for use in construction of a clandestine fission explosive--the latter threat is essentially unique to this type of reactor. This is because many research and test reactors utilize uranium that is approximately thirty times more enriched than the fuel found at commercial power reactors. The uranium found at these largely university-based non-power reactors is, in fact, "weapons-grade"--directly useable, if stolen, for use in a nuclear weapon--and thus poses a significant proliferation hazard.

It has long been recognized that the primary substantive barrier to acquisition of a clandestine fission explosive is acquisition of the weapons-grade nuclear material; the design and construction techniques are neither secret nor terribly complicated. As nuclear weapons expert John S. Foster has written:

> "It must be appreciated that the only difficult part of making a fission bomb of some sort is the preparation of a supply of fissionable material of adequate purity; the design of the bomb itself is relatively easy..."[1/]

Acquisition of weapons-grade materials has generally necessitated the use of reprocessing or enrichment facilities. A short-cut, however, is to divert or steal material already reprocessed or enriched, and that is why the highly enriched material found at many research reactors poses such an attractive target for those interested in acquiring a clandestine weapon.

"Gift-Wrapped Bomb Material"

Power reactors generally use fuel enriched to about 3% in the isotope uranium-235; Uranium of that enrichment cannot be used to make an atomic bomb. Many research reactors, however, use uranium enriched to abut 93%, directly useable in a nuclear weapon.

Furthermore, the form in which that uranium is found at these reactors--generally in flat plates alloyed with aluminum--is easily separated, providing little if any barrier to anyone who would have the requisite knowledge to make use of the uranium once separated. Extraction of the uranium is a Chem I effort, with widely published techniques and readily available equipment.

[1/] formerly Director of the Lawrence Radiation Laboratory and Director of Defense Research and Engineering in the Department of Defense; quotation in Nuclear Theft: Risks and Safeguards, by Mason Willrich and Theodore Taylor, a Report to the Energy Policy Project of the Ford Foundation, Ballinger, Cambridge, Mass., 1974

Professor James Warf[2] has described two simple methods as follows:

> "Uranium and aluminum can be separated chemically from their eutectic by any number of techniques. One method is to dissolve the eutectic in hydrochloric acid, and oxidize the uranium to uranyl ion using nitric acid. Addition of excess sodium hydroxide precipitates the uranium as sodium diuranate, but converts the aluminum to the soluble aluminate ion. Separation is effected by centrifuging. Alternatively, the uranyl nitrate can be extrated by ether of butyle phosphate, leaving the aluminum in the aqueous phase."

Theodore Taylor has described[3] a method using even more accessible materials: putting the fuel in an aqueous solution of lye and fertilizer, after five hours adding barium nitrate, centrifuging for twenty minutes at 800 G's in a standard lab centrifuge. After pouring off the aluminum solution, you would have solid U-235.

Highly Enriched Uranium (HEU), particularly in the form of plate-type aluminum alloy fuel commonly found at university reactors, is thus an extremely attractive target for someone intent on acquiring a clandestine fission explosive, in part because of the low toxicity of uranium compared with plutonium, and in part because of the dual capability of uranium to be used in either a gun-type or implosion nuclear weapon.[4] Furthermore, because the fast critical mass goes down as the square of the implosion, quite small quantities of HEU are necessary for the latter type device.

Highly Enriched Uranium in the form of research reactor plate fuel must be seen as potential bomb material. The aluminum cladding and alloy are little more than gift-wrapping.

Security Problem Exacerbated by Unique Environment

The unique security problem thus associated with the use of bomb-grade materials by research reactors is exacerbated by the unique environment in which they are often located. Whereas power reactors are located behind large exclusion zones, security perimeters, and containment structures, often far from the nearest population center, many research reactors are located without any of these protections in the center of college campuses in the midst of highly populated urban areas. In particular, despite a major proliferation threat involved with potential theft or diversion of the weapons-grade materials on site, many of these reactors are located on university campuses where stringent security measures necessary to adequately protect such uniquely sensitive materials are perceived to conflict with the open atmosphere generally associated with such institutions.

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[2] Professor of Chemistry at USC and one of the founders of the Southern California Federation of Scientists; formerly Group Leader of analytical section and inorganic chemistry section of the Manhattan Project.

[3] in McPhee's The Curve of Binding Energy, Random House, New York, 1973,4

[4] The extraction of uranium from irradiated plate-type fuel has also been widely published. See, for example, "The Processing of Uranium-Aluminum Reactor Fuel Elements" by F.L. Culler, Jr. and F.R. Bruce from the 1956 Geneva Conference on Peaceful Uses of Atomic Energy.

As will be detailed below, security at these facilities is often extraordinarily lax. Weapons-grade nuclear materials, the theft of which could have very serious international implications, are generally provided a similar level of security on these campuses as personnel records or the student store. The principal and often solitary security precaution is a readily bypassed burglar alarm system set to alarm at the campus police offices. The weapons-grade materials are kept in ordinary classroom buildings in labs not dissimilar to any other lab. Oftentimes a score of students and staff have keys to the nuclear energy labs; when keys are lost or copied without authorization, rekeying of locks is often not done. Portions of the nuclear facilities' walls are often made of glass (one such facility is almost entirely surrounded by glass walls and doors) because they were intended as showplaces; thus physical barriers to unauthorized penetration are almost non-existent. As the reactors are designed as demonstration tools, thousands of visitors per year are brought through the facilities on tours with the kind of supervision (lax) normally found on campus tours. As the reactors are often largely run by students, the problems are magnified--doors left ajar or forgotten to be locked, keys left unattended, strangers permitted entry merely by knocking on back doors, and the like.

There is often a dangerous naivete at work with regards those assigned security responsibility at these campus reactors. One such individual--a former student who stayed on at the facility after graduating and serves in the dual capacity as reactor operator and security "officer"--remarked during the course of our investigation that one should not be concerned about security problems at research reactors like his because if someone stole the fuel, the FBI would, he asserted, eventually catch the thieves and even if not, "it's real hard to make a bomb." Similarly, in a letter to the LEU Study Group by the Senior Reactor Operator at another research reactor, the assertion that its essentially unirradiated HEU might pose proliferation risks if stolen is scoffed at because the uranium is clad with aluminum. Furthermore, students or staff at these facilities charged, in addition to other duties, with security are often quite unfamiliar with the NRC safeguards regulations. Some have even interpreted the regulations as requiring no preventive or protective measures whatsoever, but merely an ability to report the theft at some unspecified time (be it days or weeks) after it has occurred.

Thus, a unique security problem, with potentially very serious international implications, exists with regards many research reactors. Unlike power reactors, their fuel is at risk for theft or diversion by a group intent on acquiring a clandestine fission explosive; and unlike power reactors, they exist in environments where security precautions are strongly frowned upon as conflicting with an open atmosphere. On the one hand, they possess material that, if it fell into the wrong hands, could result in extraordinary danger; on the other hand, security measures orders of magnitude below that which power reactors (or even everyday commercial enterprises), possessing no such bomb-grade material, have in place.

A Two-Track Approach to the Problem

For a number of years, it has been the policy of the Nuclear Regulatory Commission and other federal and international agencies to pursue a two-track approach to the problem: upgrading the safeguards at facilities possessing weapons-grade materials and attempting to convert such facilities to use of lower enriched fuels that cannot be used directly to make an atomic bomb. The latter approach is based upon the fact that use of highly enriched fuels at most research reactors is totally unnecessary and a quirk of recent history--research reactors can, and have, done everything they need to do with Low Enriched Uranium (LEU) fuels, from which weapons cannot be directly made.

These two approaches--upgraded safeguards and conversion to non-weapons-grade fuels--have had wide acceptance internationally, in the Congress, and in the agencies of several administrations.

In April, 1977, the Administration announced a policy designed to reduce the threat of proliferation by attempting to reduce the risk of theft or diversion of HEU, in part by attempting to reduce the amount of HEU in use throughout the world, particularly for research reactors. As part of that policy, DOE began a program for Reduced Enrichment for Research and Test Reactors (RERTR), designed to develop advanced fuels for conversion of even the most high-powered research reactors. The Congress passed the Nuclear Nonproliferation Act of 1978 (virtually unanimously) recognizing many of these risks. And the International Nuclear Fuel Cycle Evaluation (1980) found the reduced enrichment program of conversion of research reactors to non-weapons-grade fuels among the few positive steps for non-proliferation about which there was wide agreement.

As the General Accounting Office found,[5]

> "The reduced enrichment program is one of the few concrete U.S. non-proliferation initiatives to gain widespread international support."

This non-proliferation initiative grew in part due to increased concern about proliferation after India exploded a nuclear weapon using nuclear technology and materials supplied by the West. Since the United States provides most of the HEU used by research reactors worldwide (other than those supplied by the USSR), reduction in HEU use worldwide became a high priority.

Barriers to U.S. Foreign Policy Goals of Foreign Conversion to LEU

Among the principal barriers to achieving the U.S. goal of conversion of foreign research reactors to non-weapons-grade fuels has been foreign perceptions about whether U.S. reactors will likewise be required to convert. As the GAO commented:

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[5] "Obstacles to U.S. Ability to Control and Track Weapons-Grade Uranium Supplied Abroad" GAO Report ID-82-21, August 2, 1982, Report by the Comptroller General to Senator Gary Hart

> "A number of issues complicate the acceptance of the new LEU fuel by foreign reactor operators. Frequently foreign operators perceive that a double standard may be applied in deciding the acceptability of using HEU in foreign and U.S. research reactors. For example, the U.S. Government has not indicated whether it will restrict or inhibit the continued use of HEU in U.S. reactors. . . . The lack of participation by U.S. facilities in converting to the new LEU fuel could undermine foreign acceptance of the new fuel and, thus, negate an important part of the U.S. non-proliferation objective. Of the 156 research reactors worldwide which use U.S. - supplied HEU enriched to between 70 and 94 percent in U-235, 54 (about one-third) are located in the United States." (emphasis added)

This dependence of achieving our foreign policy goal of LEU conversions abroad upon LEU conversions at home is widely recognized. As Dr. Herbert Scoville, President of the Arms Control Association and formerly Assistant Director of the U.S. Arms Control and Disarmament Agency and Deputy Director for Research of the Central Intelligence Agency, has said:

> "The move to cut down the amount of HEU at [domestic university reactors] can have very salutary international effects as well as ones locally. It is important from a U.S. policy standpoint to make as difficult as possible the acquisition of material such as HEU that can be easily fabricated into a bomb.
>
> "However, we cannot hope to have one standard in the U.S. for availability of HEU and for safeguards on its use and a different standard for other countries. The precedent set at [domestic university reactors] will be useful in dealing with other countries such as India or Brazil as they seek HEU for their research reactors."

Dr. Scoville continued:

> "A recent example of this problem arose in Iraq. The French were supplying Iraq with a research reactor using HEU. We tried to persuade the French to provide only lower enriched material but the Iraqi government refused to accept this. When the HEU became available in Baghdad the Israelis felt it necessary to carry out a preemptive bombing raid to destroy this reactor. While I think such a violent reaction was very ill-advised, it nevertheless demonstrates the dangers of having large amounts of HEU available in locations where it might be seized and converted to a weapons program. It is perhaps more likely that a nuclear war will start with a bomb being used by a small country or terrorist organization in the Middle East than that the Soviet Union and the United States will start a nuclear war with their thousands of warheads. Therefore the control of HEU is very important, and the standards set [in U.S. domestic research reactors] should be useful in dealing with such a problem in the future."

Thus, if our goals of reducing the threat of non-proliferation are to be achieved, conversion of foreign research reactors to LEU and concommitant reduction in commerce in weapons-grade materials are essential. And furthermore, conversion of foreign research reactors appears unlikely or impossible if domestic research reactors are exempted from this policy. Moreover, because of the small quantities of HEU necessary for an atomic bomb, particularly an implosion device, and because of the difficulties in providing adequate protection for such highly sensitive materials on open university campuses, conversion of domestic research reactors from use of weapons-grade uranium is likewise necessary to prevent the potential of theft or diversion of that material.

The Commission's Commitment to Conversion

Recognizing the unique proliferation risks associated with use of Highly Enriched Uranium, the objectives of the reduced enrichment program have been fully supported by the NRC since its inception. Recognizing the necessity of converting both foreign and domestic research reactors to LEU, and the barriers to conversion of the former if conversion of the latter is not likewise required, the Commission on August 17, 1982, issued a Statement of Policy on Use of High-Enriched Uranium (HEU) in Research Reactors.[6] Indicating in that Statement that it has licensing responsibility for domestic use and for export abroad of Special Nuclear Material, including High-Enriched Uranium, the Commission committed itself to

> "...reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors."
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> (emphasis provided)

As the Commission stated in that Policy Statement:

> "In the mid 1970's, particularly following India's detonation of a nuclear explosive device in 1974, nuclear proliferation concerns began to increase. Expanded efforts were undertaken to prevent nuclear power programs from being exploited to produce nuclear weapons. Particular concerns were expressed with respect to proliferation risks associated with inventories of HEU for research and test reactors abroad. The widespread use of HEU fuel, which involved a large number of domestic and international fuel shipments, increases the risks of proliferation through theft or diversion of this material. In contrast to HEU, the use of fuel with lower enrichments reduces proliferation risks."

6/ 47 FR 37007

The Commission's Statement of Policy continued:

> "In an effort to allay concerns of proliferation risks, efforts were made to reduce HEU inventories, on the assumption that any reduction in the potential for access to these inventories would constitute a reduction in proliferation risks."

And it concluded:

> "The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. research reactor operators."[7]

In short, the need to reduce use of weapons-grade uranium both at home and abroad has been widely accepted as a responsible and necessary policy. It is one of the few non-proliferation initiatives to have widespread support, in part because it is a sweet technical fix: research reactors can continue to do what they are doing now, but with fuel that doesn't pose a proliferation hazard if stolen or diverted. In fact, it is a very conservative policy--returning many reactors merely back to their original designs.

It is one of the ironies of this entire dilemma that it is largely an accident of history, perhaps a victim of short-sighted policies of the past. In the 1950s and 1960s, low power research reactors were built in many countries, including the U.S., which utilized fuel containing 20% or less enriched uranium, a value chosen because it was considered to be a limit for weapons usable material.[8] Highly enriched uranium came into demand for high power research reactors, and eventually many low power research reactors for which low enriched uranium would have sufficed were using HEU instead (sometimes even converted from LEU use). After the detonation of a nuclear device by India, concern over weapons-grade materials spread, and now research reactors are going back to low enriched fuels. It is one of the best indications of the lack of technical barriers to solving this problem that many of these reactors were originally designed to run on LEU; if they ran on it once, they can run on it again. Furthermore, reactors of different design can readily and without difficulty convert to LEU fuel, even fuel of different form than previously used. An interesting case is the University of Maryland which, some years ago, anticipating that the NRC would at some point require conversion to LEU, converted from HEU plate fuel to LEU TRIGA fuel.

Another interesting example is the University of Florida Argonaut-type reactor. The original Argonaut at Argonne National Labs used 20% oxide plate-type fuel. When the University of Florida Argonaut was built, it used metallic plate-type fuel, also 20%--expressly indicating it did so to minimize the need for security precautions.[9] It eventually converted to 90% enriched plate fuel, and is now in the process of converting once again, as part of a DOE demonstration project, this time to 4.8% LEU in the form of oxide rods. They report no major difficulties and view their experience as a prototype for other similar low-power research reactors.

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[7] Commissioner Roberts added a footnote expressing concern about the steps not being specified.

[8] See IAEA-TECDOC-233, LEU Conversion Guidebook, Int'l. Atomic Energy Agency, 198

[9] See 1958 Hazards Summary Report, University of Florida

Conversion of most research reactors is technically feasible now with current technology and is not difficult, involving primarily replacing HEU fuel with LEU; conversion of all but a very few high power research reactors will be readily done in the very near future with advanced fuels nearing final development by the RERTR program; and the Commission is pledged to a Policy of converting both domestic and foreign research reactors, "to the maximum extent possible." The maximum extent possible, in light of the lack of technical barriers, will represent a substantial reduction in the number of research reactors here and abroad using weapons-grade uranium.

Implementation of the Commission Policy on Conversion

After committing itself to converting, "to the maximum extent possible," domestic and foreign research reactors to non-weapons-useable fuels, the Commission began to solicit advice as to how to implement that formal Policy.

U.S. research reactor operators, who, as the Commission noted, "have shown little interest in converting to lower enrichment fuel," came forward with a proposal which essentially says that the Commission's Policy should be implemented by exempting all but a handful of domestic research reactors from the Policy.

The licensees' proposal, forwarded to the Commission by the Office of Policy Evaluation (OPE) after a meeting with industry representatives, made two recommendations which are somewhat deceptive in their simplicity. Their effect, however, is clear: if adopted, the Commission's August 1982 Policy would be gutted or overturned.

The two proposals are:[10]

- No new research reactors would be licensed to use HEU unless they could make a case they needed it.
- Existing research reactors when they replaced their cores would have to use LEU replacement fuel, unless they could make a case they needed HEU.

The recommendation paper, however, is quick to point out that the impacts of such an implementation procedure on the affected industry would be essentially non-existent because:

- No new research reactors are expected to be built in the foreseeable future, due in no small measure to the radical decline in enrollments in nuclear engineering programs. Research reactors are getting closed down for lack of use; no new domestic research reactors are expected to be built.
- The vast majority of research reactors, due to low burnup, would not replace their HEU cores. They would thus be exempted from the Policy of conversion.

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[10] transmitted by memo, Zerbe to Ahearne, March 1, 1983

It is clear that if the purpose of the Commission's Policy is to encourage conversion of foreign research reactors to non-weapons-grade fuel, the domestic industry's proposal of exempting all but 3-5 of U.S. research reactors from such conversion requirements is likely to strongly undercut our ability to persuade foreign operators to do something we are unwilling to require domestic operators to do. Likewise, if the Commission's Policy is, as stated, to reduce to the maximum extent possible amounts of HEU available, exempting 90% of domestic research reactors from such a Policy will gut it. If HEU use, as the Commission has said, "increases the risks of proliferation through theft or diversion of this material," and if, as it has also said, "the use of fuel with lower enrichments reduces proliferation risks," adoption of the industry's proposal for virtual across-the-board exemptions from the Commission's Policy can only increase proliferation risks.

The Licensees' Request for Across-the-Board Exemption from the Policy

There is currently little incentive for research reactor operators to convert to non-weapons-grade fuels, and so their opposition to the Commission's Policy in this regard is not unexpected. The primary potential incentive--protection from upgraded safeguards requirements if not in possession of HEU--has been mitigated by what was to have been a temporary deferral of the Safeguards Upgrade Rule while the RERTR program made available LEU fuels. Furthermore, the licensees' proposal to essentially overturn the HEU Policy is combined with proposals on two related matters that would drastically reduce both incentives for conversions and adequacy of protection of the facilities: the proposal to significantly weaken physical security requirements for protection against theft of HEU, and to abolish altogether long-standing requirements to protect against sabotage. While one can understand why the licensees' would like to roll back all three of the Commission's safeguards practices, it must be said that such an attempt is extremely short-sighted.

Just as the TMI accident dealt a staggering blow to the commercial nuclear power industry from which it has yet to recover, a breach of what limited security there is at research reactors could have devastating effects. The implications of theft of kilogram quantities of weapons-grade materials should give pause to those representatives of the licensees who have pursued abolition of these Commission safeguards policies because of the inconvenience they might cause the licensees. That inconvenience is miniscule compared to the potential consequences involved with a major safeguards incident.

The "LEU Study Group" Report to the Commissioners:

A report was commissioned by the NRC on an "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Fuel," under a $59,053 NRC contract.[11]

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[11] Contract no. NRC-04-83-179

Inexplicably, the contract did not go to an independent research entity, without financial interest in the proposed regulation being assessed. Rather, arrangements were made with an organization representing the licensees--the Nuclear Engineering Department Heads Organization (NEDHO)--to set up the Study Group to conduct the research.[12]

The researchers chosen through this arrangement with NEDHO were thus all representatives of the potentially affected licensees. They included a member of NEDHO, as well as the current head of the other main licensee organization known as TRTR (Test, Research, and Training Reactors organization). The Group thus consisted of two university faculty directors and two staff managers of the reactors being assessed.[13] In one of the more awkward aspects of this arrangement, the Chairman of the Study Group was in the unique position of participating in the design of the survey, responding to it as a representative of a licensee, and assessing that response. This led to the situation of having to sign a letter addressed to himself, answering questions he had posed and thereafter assessing answers he had provided.[14]

While in no way calling into question the technical qualifications of the participants, the composition of the Study Group--composed as it was exclusively of representatives of the affected licensees and their organizations--is unfortunate. The affiliation of the authors with the licensees who are under threat of the proposed regulation will be seen by many as coloring the conlusions reached.

Chairman Palladino has been quoted as saying regarding the appropriate standards for NRC research contracts that it is "definitely unethical" for an entity under threat of regulation to do research relating to that regulation. (Inside NRC, June 29, 1981). That is sound public policy; otherwise agency funds intended for independent research could instead be going to advocates of the affected licensees to tell the agency why it should not implement an important public policy regarding them.

That the Study Group viewed the purpose of the survey as advocacy of the interests of the affected licensees is made clear in the survey letter sent out to the research reactor representatives:[15]

> "The purpose of this letter is to inform you concerning the matter /i.e., that the NRC is considering a regulation that could require, the letter said, "immediate replacement of the cores of those existing reactors capable of using LEU"/ and to request certain written material in support of university interests."
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> (emphasis added)

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[12] See LEU Study Group report, p. 1
[13] id.
[14] id., p. 55 and 126
[15] id, at 53

Problems With the LEU Study Group Report: Barriers to Conversion Overstated, Benefits Downplayed

It is interesting to compare the conclusions of the study performed under the auspices of the research reactor licensees' organization with those reached by Gerald Pollack in a study performed for Commissioner Gilinsky.[16/] The Pollack study concludes, "The reactor administrators are generally in favor of the conversions to LEU and would be cooperative." He goes on to conclude:

> "Now would be a good time to move rapidly on converting university reactors to LEU since: (a) the reactor people are generally in favor, (b) NRC and DOE are seriously interested, and (c) most of the technical problems are solved or seem to be near solution."

These conclusions are echoed in numerous of the responses to the LEU Study Group's survey, yet the Group's conclusions are at right angles to Pollack's--the Group essentially opposes the Commission's Policy in its entirety, arguing that if it must be enforced at all, convert only three to five research reactors (one of which has already been successfully converted) and exempt all the rest.

In advancing this suggested reversal of the Commission's August 1982 Policy (converting "to the maximum extent possible"), the Study Group advances a number of supposed barriers to converting most research reactors, barriers that, upon closer examination, appear considerably overstated. Most of the barriers are not barriers at all, but rather inconveniences--inconveniences that pale in comparison to the consequences should any of the weapons-grade material currently on site at these university reactors be stolen.

A Unique Definition of Technical Feasibility

Research reactors--despite the fact that many of them originally ran on LEU and that many others have since been converted to LEU--when the issue of conversion for proliferation reasons was first advanced by government agencies in the late 1970s were often argued to be technically incapable of operating on fuel of any lower enrichment than the weapons-grade level they are currently using. It was argued that the thermal neutron flux would dramatically drop, reducing the usefulness of the reactor as a tool for activation analysis and similar processes; some research reactor operators went so far as to assert it would be technically impossible to even go critical with an LEU core. (An example of how this misconception continues can be seen in one of the reactor operator's responses in the LEU Study Group report at p. 130, where a critical facility--requiring no excess reactivity and having no burnup--with plenty of empty spaces in the core grid is asserted to be incapable of attaining criticality without an HEU loading.)

It is now widely recognized that there are no real technical barriers to conversion of all but perhaps a couple of reactors. One simply uses fuel that compensates for the lower enrichment by increased uranium density. It

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16/ "Converting Reactors At Academic Institutions from HEU to LEU", Sept. 22, 1983 is a simple matter essentially of removing the HEU fuel in the core and replacing with LEU fuel. If the fuel is of the same dimensions, nothing else alters; if the dimensions are different, there is a slight change in plate spacing which, particularly for all but the high power reactors, is largely inconsequential. The so-called "major" license amendment conversions described in the LEU Study Group report are merely those conversions, which if done now rather than waiting a couple of years for higher density fuels, would involve plate spacing being different than at present.

It should be recalled that the increase in density is not a major change. Plate-type fuel in particular is a dispersion type of fuel, with small amounts of uranium dispersed in a matrix of aluminum. Aside from one or two domestic university reactors, LEU fuel is either now available or will shortly be. The barriers are solely political, not technical. To enforce the Commission's Policy of reducing "to the maximum extent possible" HEU at domestic research reactors would mean conversion of all--or almost all--university reactors.

Similarly, there is no technical problem regarding flux. Flux is essentially unchanged; at best a 10% thermal flux drop, meaning that for those few applications where a 10% difference might be important one irradiates 10% longer time or at 10% greater power. For almost all research reactors, a 10% reduction in thermal neutron flux would have no effect on activities whatsoever. (It should be noted that many research reactors don't know their thermal neutron flux to anything like a 10% accuracy anyway; oftentimes flux measurements were made twenty years previous, by students, with contradictory results, and flux is generally reported to only an order of magnitude accuracy--e.g., 10^{11} n/cm^2-sec.)

There are no technical barriers.

However, the LEU Study Group report discusses what it calls such technical barriers by a rather unique definition of "technical feasibilty." The Group defines technical feasibility as anything that can be done costing less than 1% of the reactor capital cost and change in flux or operating costs of more than 5-10%.

The LEU Study Group's definition of "technical feasibility" is thus not one of technical feasibility at all but one of economic desirability. And it establishes a unique cost-benefit assumption: that costs in excess of a few thousand dollars (most of these reactors cost between $100,000 and $1,000,000 to build) outweigh the benefits of preventing a group or nation from acquiring weapons-grade nuclear materials and making a clandestine atomic bomb therefrom. This cost-benefit starting premise colors the entire rest of the analysis, because it so vastly understates the international implications of acquisition of a clandestine fission explosive and the undermining of our attempts abroad as well to reduce stockpiles of weapons-grade materials that could be stolen or diverted.

In fact, throughout the report, there is at best a few sentences mentionining the benefits of conversion in terms of reducing proliferation risks. The report assesses the Commission Policy's implications by measuring exaggerated time and financial costs against un-weighed and un-assessed risks of nuclear weapons proliferation. Measuring one without assessing the other skews the results and leads to the reactor operators' recommendation that the Commission not enforce the Policy.

Functional Impacts Overstated

The reactor operators assert conversion could take as much as 120 months per reactor to achieve. This simply is a paper tiger. A careful reading of the responses by the licensees indicated that the actual time for conversion involves down-time of the reactor of a few weeks. One shuts down, unloads HEU, and reloads LEU. Fuel loading and unloading are common occurrences at these facilities; such a function is standard whenever core maintenance is done or fuel added to increase excess reactivity, compensate for burnup, or check for fuel damage.

The start-up tests after reloading with LEU have also been overstated. A careful review of the responses indicates that these start-up tests likewise would be minimal, of a few weeks in duration. Furthermore, the benefits of such tests are ignored. One reactor operator indicates that previous start-up tests were done in part by students at the facility. That is standard--these are, after all, supposed to be training facilities. One of the reasons that use of these reactors for educational purposes has so severely declined in recent years is that the truly vital educational and research periods for them were within the first few years after start-up, when the fuel was only lightly irradiated and in-core experiments (other than simple sample irradiations) could be performed. Reviewing student theses from a number of these reactors, for example, indicates a rapid decline in such student projects after the first few years, often admitted directly in licensee documents to be because the kinds of experiments students could do were no longer possible with the irradiated fuel.

For example, one of the primary start-up tests to be performed is a measurement of the void coefficient of reactivity--what the effect is on the reactivity of the system by a certain fraction of the moderator being voided, as from boiling. This is extremely important for evaluating the safety of research reactors from the potential for a destructive power excursion of the sort that destroyed the SL-1 reactor in Idaho in the early 1960s. Many research reactors have not measured that value in twenty years. It is a good student project; it involves placing substances which simulate voids in various locations in the core and measuring changes in control rod position therefrom. To do it, however, requires relatively non-irradiated fuel because of the direct contact with the fuel involved.

The few start-up tests thus necessary--measurement of void and temperature coefficients of reactivity and flux distribution within the fuel--would take a few weeks, be good student educational projects as they were when the reactors were new, and would improve safety at the facilities by providing recent measurements of key core parameters.

Down-time involved with conversion has thus been severely overstated, as is the loss in revenue due therefrom. (Many research reactors, having had research and instructional functions decline significantly since their early days, now are used to a significant extent for sale of irradiation services commercially.) These reactors must shut down for core maintenance from time to time anyway; any experiment involving insertion of a major experiment into the core often requires core entry; and the reactors were designed for ready few removal and insertion, as that is how they are re-fueled, made ready for maintenance, and made useful for certain internal experiments. We are talking a few weeks of down time, perhaps scheduled to coincide with regular maintenance, best scheduled during academic vacation or times between quarters.

The major time asserted to be involved in the conversions involves preparation of the safety analysis report. This seems to severely overstate the reality of the situation. Many of these reactors have in the past made far more substantial modifications to their facilities than is involved with putting in LEU fuel in the place of current HEU. Many reactors have vastly increased excess reactivity loadings, changed coolant systems, upped power levels, put in pneumatic tube systems, changed irradiation facilities, and the like. The Safety Analyses performed, based on a review of scores submitted to AEC and NRC, have tended to be quite short, taking at best a few staff-weeks to prepare. In fact, a review of the licensees' letters contained in the LEU Study Group likewise indicates many think such safety analyses could be completed in a period of a very few months; this does not mean, by the way, nothing else goes on at the facility during that time, just that as part of the normal course of business (doing safety analyses on proposed engineering modifications that come up from time to time, or new experiments proposed) an analysis is performed of taking out HEU and putting in LEU. The Analysis would make an excellent project for a reactor director and a graduate student or two, perhaps even with portions provided as class projects by a nuclear engineering class.

The time necessary to wait before off-shipping the old HEU seems overstated in the Report also. It appears from a review of the supporting licensees' responses that the only technical limitation is reduction of dose rate of the old fuel, which drops rapidly. The highest power reactors report a need to hold of only 3 months--the several years indicated by one of the lower power reactors as preferable is based simply on the fact that in the past they didn't get around to off-shipping old, lightly-irradiated HEU for several years. Off-shipment could be accomplished a few months after reloading with LEU, and of course that time period represents no interference with normal activities of the facility, as the old fuel is simple in storage holes or pools.

In short, conversion is physically easy (just taking out old fuel and putting in new), the ancillary tasks (prior safety analysis and post start-up tests) are short in time scale and useful educational experience, as well as having some safety benefits.

Financial Costs Overstated

The licensees' estimate conversion costs, if all university reactors other than MIT and Missouri-Columbia were converted, would be a total of $9 million for fuel fabrication and transportations costs, and $6 million for non-fuel costs associated primarily with preparation and defense of safety analyses for the conversion. These figures are grossly inflated.

They assume, for example, $250,000 of safety analysis costs per reactor, even if a minor license amendment is required because same-size plates are used and no change is made in thermal-hydraulic characteristics (i.e., plate-spacing is the same). This is absurd. Most reactor facilities spent far less than an order of magnitude on all safety analyses ever performed at the facility--including the original one and ones for very major modifications. The entire purpose of the RERTR program is to prove the conversion technology and resolve any potential safety problems (none have really come up). Once RERTR has proved and demonstrated a particular LEU fuel, the particular safety analyses tasks and costs for the particular reactor involved will be minor. This is particularly true if the Group's proposal--a good one--involving lead reactors for each major reactor type is followed. In that case, only those very few characteristics which vary between largely identical members of the same model of reactor would have to be assessed by the licensee, with a generic analysis already having been performed that assesses the impact on reactors within that class.

Most of the $6 million estimated for non-fuel costs would not occur.

As to the $9 million estimate for fuel fabrication and transportation, that too seems quite high. At $500 per plate, a new core for most reactors would be about $132,000, half or a third that estimated in the Report. For the higher power reactors which use up several cores, the actual fuel cost of conversion could actually be less than for the lower power cores, because it is only the incremental difference between what LEU fuel would cost and what it would have cost them anyway to buy HEU.

The shipping costs seem inflated as well. Actual shipment costs for a kilo of spent HEU were less than $5000 and the primary costs are a mileage fee for the truck and drivers, irrespective of amount carried. Even assuming two armored escort vehicles and tremendous distances for travel (Joplin Missouri to Vallecitos California to a Washington State reactor to Idaho Falls back to Vallecitos to return the cask and back to Joplin) the shipping costs for all HEU at most research reactors would be $29,000, almost all of which is involved with transport of the truck from Missouri, not the transport of the fuel to the repository. These costs would thus plumet if many reactors converted and shipments were coordinated so that the truck did not drive half way across the country to and from Joplin empty.

True conversion costs seem more representative in the estimates at page 27 of the Report of $190,000 for all fuel and non-fuel expenses (although there the shipment costs still seem very high). This is considerably less than the $350,000 fuel costs and $250,000 non-fuel expenses assumed in the report per reactor, a total of $600,000 per reactor. Using the more reasonable figure, converting all but MIT and U of Mo-Columbia would cost thus less than $5 million dollars.

It could even be done far more cheaply. The University of Florida reports in the LEU Study Group report and elsewhere that it is converting from HEU plate type fuel to 4.8% SPERT oxide rods of which it has a large quantity that were donated to it from the old SPERT power excursion testing program at Idaho Falls. That fuel is thus free.

When the University of Florida says they have a "lot of " this LEU, they mean it. They have approximately 5400 pins containing 188 kgs of U-235. Under a DOE contract, they have been converting in a demonstration project. The conversion will double their flux, not reduce it, they report, and is applicable to other similar reactors. Certainly the other four Argonauts could convert similarly, with perhaps no fuel costs at all.

Lastly, the LEU Study Group report makes a big deal of potential licensing problems and the need perceived by the licensees to keep the public out of any licensing action. While understandable, such would be a serious mistake, but at any rate misperceives potential problems. It is Intervenors who are asking for conversion to LEU, and licensees who are resisting. This is a unique opportunity to avoid public hearings by taking an action that would reduce or eliminate public concerns. To fail to convert may end up costing far more.

Safety Benefits Understated Also

Conversion to LEU has numerous safety advantages as well as safeguards advantages. The Report downplays these. They are significant.

The design basis accident for most research reactors is a power excursion initiated by, for example, someone inserting a highly absorbing sample for irradiation, withdrawing control rods further to compensate for the neutron absorption, then withdrawing sample but forgetting to first reinsert control rods. It assumes that the maximum available excess reactivity is inserted into the reactor (as by withdrawing the negative-worth sample), that the reactor goes onto a power excursion in which power is increasing exponentially at a rapid rate (with e-folding times usually in the millisecond range); the reactor is considered inherently safe if the excursion is self-terminated (by negative temperature and void coefficients) before the fuel has melted or otherwise been damaged. A power excursion that was non-safe would be, for example, the tragic SL-1 accident in the early 1960s in which the fuel not only melted but a substantial portion vaporized and in which the core was disassembled by a steam explosion.

Conversion to LEU can have a very substantial favorable impact on reactor safety. The primary problem with power excursions in plate-type reactors is that there is a time lag in the activation of the self-shutdown features. Temperature must rise in the fuel meat, be transferred to the clad and from there to the coolant, coolant must vaporize and water be expelled from the core region. This takes time; in an event occurring on the millisecond time scale, the exponential rise in power may be faster than the time lag associated with the shutdown mechanism.

LEU, in contrast to HEU, has a sizeable Doppler effect due to the presence of U-238. The U-238 heats up virtually instantaneously; there is no time lag; it becomes a more effective neutron absorber; the excursion is promptly turned.

In power excursion tests at SPERT (Special Power Excursion Reactor Test) at the National Reactor Testing Station in Idaho, cores using LEU were found to be significantly more resistant to damaging power excursions than were cores using the HEU plate-type fuel found at many research reactors currently.

Furthermore, one of the LEU fuel types currently available--for conversion of both plate type and rod-type reactors--is TRIGA fuel, with part of the moderator built into the fuel itself. It too has a very prompt and strong negative temperature coefficient, far more resistant to damaging power excursions than plate-type HEU. (The SL-1, Borax-1, and Spert-ID, all destroyed in destructive power excursions were all fueled with plate HEU. It is possible to destroy a reactor with LEU or TRIGA fuel, but the reactivity insertion necessary to do it is generally far greater.)

The LEU Study Group asserts that the safey of LEU and HEU is roughly the same. This seems to understate the real safety advantages of LEU in the power excursion area. (The assertions about slightly smaller neutron lifetimes and delayed neutron fraction seem insignificant. It is to be noted, further, that at SPERT II it was found that long neutron lifetimes may not be beneficial, because just as the neutron lifetime determines how rapidly the power rises, it also determines how slowly the excursion is terminated. At SPERT II, fuel damage was found at exponential periods ten times longer than at a reactor with shorter lifetime.) The prompt temperature coefficient due to the Doppler effect in U-238 is a very important safety feature; the even more prompt feature in TRIGA LEU even more so.

Furthermore, use of an oxide LEU (as in the case of the SPERT fuel being used by the University of Florida) can substantially reduce the fire danger and risk of fuel melting. The U-AL alloy used in HEU plate fuel is flammable; an oxide fuel is far less a risk in a fire as it is already, partially at least, oxidized. Furthermore, the U-AL fuels used in HEU are in the eutectic range, very low melting (about 650^{o}C); TRIGA and oxide fuels would have substantial protection due to a very much higher melting temperature.

Thus, conversion to LEU provides not only substantial safeguards benefits, but also safety.

The Artificial Construct of "Lifetime Core"

The licensees' proposal to essentially throw out the Commission's August 1982 Policy is based in large part on the artificial construct of reactors claimed to have "lifetime cores." This implies that the fuel in the core will never need to be removed because of very low burnup and therefore fuel reloading would never be necessary unless LEU conversion were required. This is somewhat misleading.

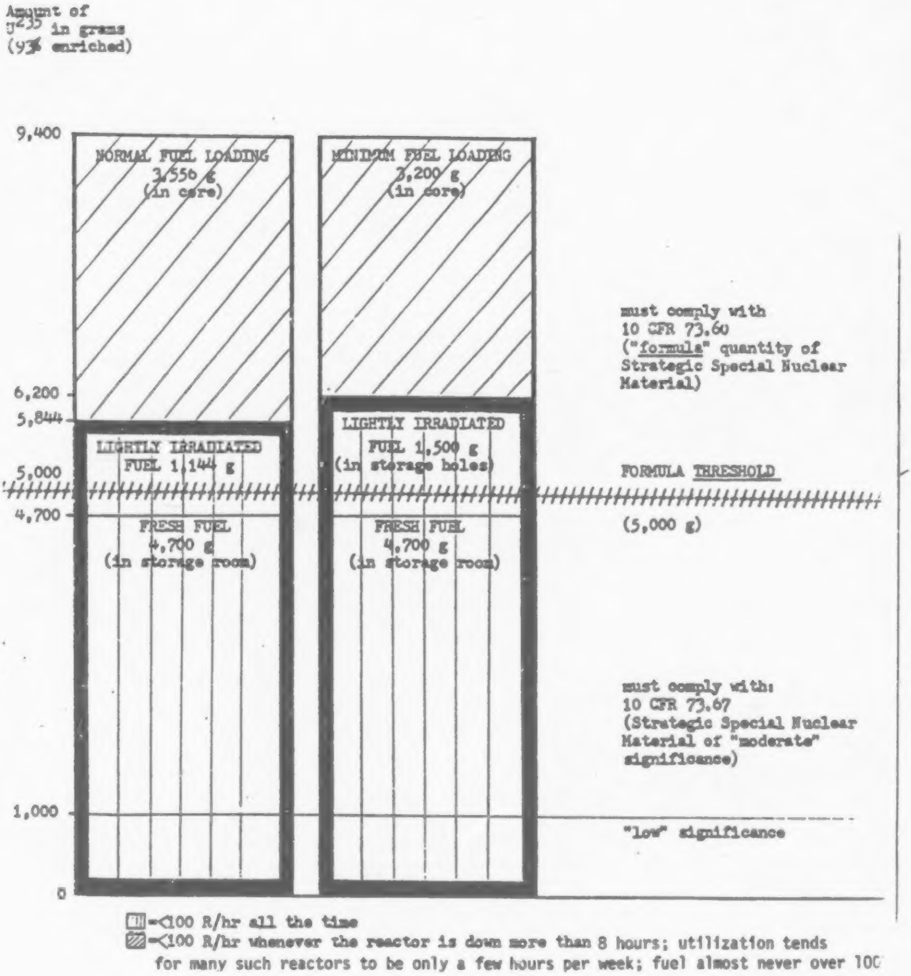
First of all, the definition of "lifetime core" used in the LEU Study Group report is actually that a reactor would not need to order new fuel in the foreseeable future because it could keep operating with the fuel in the core, in storage, or currently on order from a fabricator. This is a far-cry from what one might first think when hearing the term "lifetime" core.

The standard university reactor with HEU has a few kilos of HEU in the core, generally relatively lightly irradiated, and then other kilos of HEU in storage. The total on site is either a hair below the "formula" quantity of 5000 grams or considerably above. Thus, Washington State University would be considered a "lifetime core," for example, even though it has license authorization to possess 20 kilograms of HEU, and burns up only about .04 kilograms per year of U-235. It is "lifetime" solely by virtue of the amount of fuel in storage or on order. The same must be said of most of the so-called "lifetime cores."

One must ask, if these lifetime cores burnup so little fuel and supposedly would not need to reload in the next two decades, why have on site thousands of grams of unirradiated HEU? If the radiation of the irradiated fuel makes it somehow less of an attractive theft target, why have any of this more attractive material around if these indeed are genuinely lifetime cores?

Part of the answer to the question is that addition of fuel to these reactors is a common occurrence, happening every few years. Fuel will be damaged, thought to be leaking, or removed to increase the excess reactivity of the cores. Thus it is standard practice at even the low-burnup reactors to add fuel regularly. They are clearly not "lifetime." All that is being said is: "listen, we've got lots of this HEU on site and on order--let us use it up. If you do that, we won't have to convert." The problem is that with that lifetime arguement those reactors will, for their lifetimes, have HEU on site, attractive for theft, largely unprotected, posing a significant proliferation threat. The entire purpose of the August 1982 Policy Statement and the various initiatives on reducing HEU inventories is to prevent research reactors from having for their lifetimes inventories of weapons-grade uranium available for theft at any point in the next few decades.

SAMPLE "LIFETIME" CORE



▥ =<100 R/hr all the time

▨ =<100 R/hr whenever the reactor is down more than 8 hours; utilization tends for many such reactors to be only a few hours per week; fuel almost never over 100

The Licensees' Proposals

The Study Group recommends that no reactor with a "lifetime" supply of HEU on site be required to convert; that conversions of the rest (a handful) only be required when there is LEU available that would not require changing plate spacing; that priority be given to the high power reactors; and that other exemptions be provided. The long and the short of their proposal is to require conversion only of three or so reactors, if that.

The priority for high power reactors is not necessarily correct--they are the ones that may require a few years more work on advanced replacement fuels. LEU is essentially available now for the rest. And it is the lower power reactors, with their very low irradiation levels, that have the attractiveness of ease of theft and use.

The Commission has already its Policy--convert reactors "to the maximum extent possible." It is possible to convert them all; careful scrutiny would be necessary to see if MIT and U of Missouri-Columbia should be given exemptions.

Essentially all of the research reactors could be converted using currently available technology; this would involve for some the minor change of slight alteration in plate spacing. If one were to avoid any dimensional changes, about half could be converted now, the other half in a couple of years. The Commission's priorities should thus be to convert those now that can be converted now; those that should await further development of same-dimension fuel for a couple of years should begin the planning stage now and be in the second wave of conversions.

The five TRIGA reactors can all be converted to TRIGA LEU, and should be. The five Argonaut reactors can all be converted to SPERT-type LEU as at University of Florida, or to simple LEU in flat plate with technology essentially available now. Georgia Tech, and the Medium and Low Power MTR-type reactors can all be converted with technology available this year or by two years from now at the very latest (with the possible exception of Kansas State). UCSB's liquid reactor can be converted now. There is no technical barrier whatsoever; the costs are minimal; the benefits immense.

Costs

Complete conversion of university research reactors to non-weapons grade fuel could be accomplished for $5 to $7 million dollars. Even taking the licensee's figure of $15 million, believed to be considerably inflated, that remains a small fraction of the RERTR budget (expected to total $50 million upon completion.) If we are willing to spend $50 million to research conversion, we certainly should be willing to spend $5 to $15 million to carry it out.

Impossibility of Successfully Carrying Out Foreign Policy Goal of Converting Foreign Research Reactors If We Do Not Convert Domestic Reactors

Even assuming the cost if $15 million, and even were there no proliferation advantage to eliminating HEU inventories at home, that expenditure (quite small in the scheme of things) would be worth it alone on the basis of encouraging foreign conversions. Our foreign policy goal of conversions of foreign reactors will not succeed if we do not convert our own. As Dr. David Hafemeister, formerly Special Assistant to Under Secretary Benson and Deputy-Under Secretary Nye in the Department of State in the late 1970s on nuclear non-proliferation matters, has written:

> "Failure to /‾reduce HEU at home through conversion of domestic research reactors_/ would damage U.S. foreign policy interests by undercutting our government's attempts to reduce international commerce in HEU and convince other nations of the need to reduce their HEU holdings and the enrichment of their research reactor fuels. I know from personal experience in representing the State Department in such interactions with Chilean nuclear officials and representatives of Atomic Energy Commissions of other nations that it will be much more difficult for the U.S. to succeed in its policy of reduced enrichments and HEU holdings abroad if the policy is not vigorously pursued at home. The inconsistency of the US, on the one hand, denying HEU to foreign research reactors while, at the same time, oversupplying research reactors at home with HEU that is not properly safeguarded would not be lost on the nations we are trying to influence."

$5, $10, or $15 million spent to convert domestic university reactors--if for no other reason than to remove a major stumbling block to conversion of foreign reactors--would be money very well spent. The same amount spent to prevent diversion or theft of HEU from U.S. reactors would also be well spent. Put together, it's a real "steal."

The Alternative to Conversion: Effective Protection Against Theft

The Commission has essentially two choices on the matter of HEU at university reactors: convert them to LEU, or force them to protect the material consistent with the consequences of its theft or diversion. If the university community is worried about the impacts of the former, which would be minimal, they should be very worried about the impacts of the only other choice that failure to convert would leave open to the Commission: significantly upgraded security.

When the Commission approved the Safeguards Upgrade Rule in the late 1970s, nonpower reactors were temporarily exempted from its effect. That deferral was to be short-lived, based on the soon-to-be available LEU conversion fuels being developed by RERTR. Those fuels are now essentially available, and either research reactors should be converted, or protection upgraded.

The licensees have proposed that they have their cake and eat it too: that they be exempted from LEU conversion and that physical security requirements for HEU be largely relaxed. Both proposals go in the wrong direction.

The Need for HEU Conversion in Perspective: HEU As It Is on These College Campuses

The fuel at most of the reactors with HEU cannot be kept anywhere near the 100 Rem/hour level.It is protected almost exclusively by relatively primitive and easily compromised burglar alarm systems, alarming at campus police stations, with relatively untrained "unicops" to respond as they would to any alarm on campus. There are few if any physical barriers to entry of any effectiveness, and the fuel is readily removeable. The Los Alamos study performed for the Commission on this issue estimates removal of the HEU at the standard research reactor could be accomplished in 1.25 hours, with times as low as .5 hours possible.

Universities pride themselves, rightly so, on their open atmosphere. The kind of security necessary to protect atomic bomb material is inconsistent with that atmosphere. That explains a large part of the reason why research reactor licensees have lobbied the Commission so hard to relax or defer or eliminate entirely physical security requirements for protecting against theft or diversion of the highly enriched uranium they have on campus.

That simple understanding--that protection sufficient to protect bomb-grade material from theft is inconsistent with the environment in which that material is found at these research reactors--speaks volumes about the need to convert these facilities from HEU to LEU. Security cannot be--and is not--anywhere near sufficient to protect material of this incredible sensitivity. Either the universities should agree to truly safeguard this material--which they refuse to do--or they should not have it on site. They can do all they wish to do with LEU and not have the security problem presence of weapons-grade material produces. An examination of the situation at many of these research reactors is helpful in putting in context the HEU policy issues.

Bomb-Grade Material in Filing Cabinets, Walls of Glass, Inoperable Alarms

The following examples of security problems at research reactors possessing HEU are taken from a survey of approximately 1/3 of those in the nation. The material all comes from information in the public record. However, although we were able to obtain the material from public sources, we do not feel it appropriate to identify with specificity where each particular problem is associated with which particular reactor. Potential thieves of HEU can get too much information on that score already. It should be understood, however, that this material comes from inspection reports and other publicly available material about a number of university-based reactors and should not be assumed to pertain to any specific one.

** One research reactor, built twenty years ago when the campus wished to make the reactor a campus "showplace," was built with essentially all walls and doors made out of glass so that people passing by could see directly into the reactor room. Inspectors years later expressed concern about this from a security point of view--glass walls do not provide much barrier to penetration!

** At another facility, one key was lost and another duplicated without authorization, yet the inspectors found that one year later there had still been no corrective action (i.e., no rekeying).

** At another facility, the security plan requires the alarm system to register a security violation (i.e., the alarms must work). The inspector cited the licensee for violation of this requirement when he had the alarm system armed and walked around the reactor room for a considerable period of time without being able to set off the alarm!

** Similarly, an inspector found a reactor security system to have been plagued with false alarms, so the licensee had "tuned down" the alarm sensitivity to a level that made it impossible to detect intrusion. Further, it was found that the alarm system installed by the licensee was a kind that the AEC had found defective and forbidden for use in AEC facilities.

** Another such alarm system was found to be tied into the computer at the campus police station. It was found that this was a problem because of the relative ease in disabling the computer, or modifying its program (a forerunner perhaps of the recent reports of teenagers entering and altering other people's and institution's computer systems.)

** It was found at one facility that at certain times there was only one campus police officer available to respond to an alarm at the reactor, and that furthermore there were no procedures as to what to do once there nor who to call on for support if needed.

** One report cites the requirement that "key locks should provide a high degree of resistance to opening by force or tamper techniques.... / However / In several of the locks it was noted ...failed to operate." "The inspector demonstrated to licensee staff that the door ... could be opened using a small screwdriver."

** In another facility, the doors to the reactor facility were all built with the hinges on the outside, making possible easy entry into the facility without even having to tamper with the locks. Simply by removing the hinges one could gain entry by essentially removing the door itself.

** Another inspection report revealed nuclear material "unaccounted for" (MUF), inventory record poor, poor burn-up records, no inventory procedures, "internal controls were minimal"

** Another report found a violation at a particular facility because keys had been given out to people without their taking the required training.

** In other situations, keys had been given out to people who had later left the university without the keys being retrieved or the facility rekeyed.

** At another institution, an inspector cited the licensee for having left the key to the reactor in the control console without anyone present; the key could thus have been taken by anyone nearby.

** In other facilities, the key to the reactor must be given to maintenance people whenever they are to do maintenance in a non-reactor related room restricted entry because of "gamma and neutron shine". Thus, a vital key is given out for long periods because the facility didn't spend the money for a true interlock system that would have prevented personnel above the reactor room while the reactor was on.

** Another facility was found to have "no material control and accounting proceedures"

** Drawings in the security plan were incomplete--ten feet were missing from the center of the building drawings.

** The facility built of glass had other problems: "The south side of this building is particularly vulnerable in that trees and shrubs prevent an isolation zone. In addition, bricks are stacked near door '5' that would completely mask a potential intruder."

** It was observed at one facility that people were given entry to the building by a student inside opening the door when people knocked. Methods of preventing unauthorized persons from knocking and forcing entry when door was opened weren't in place.

** "Effective key controls have not been established. For example, a master key issued to an individual no longer on the faculty has not been retrieved and three master keys are known to have been lost. However, the locks associated with those keys have not been rekeyed.

** "There were no specific procedures for response to alarms by campus police and no provisions for compensatory measures in case of alarm system failure."

** The alarm system at one facility didn't differentiate between alarms at the reactor and elsewhere in the building.

** "There is no commitment in the security plan to periodic key inventories and other provisions of Regulatory Guide 5.12."

** "The reactor control room is not locked during times of occupancy."

** "Discussions with operations personnel and examination of records of the Campus Police Department revealed that on September 13, 1977, the east door to the Nuclear Reactor Building was found unlocked by campus police at 0207 hours. The Nuclear Reactor Building was inspected by the police and then secured."

** A facility was found to have defective door locking mechanisms and committed to correcting the problem. A year later the next inspection found the commitment had not been lived up to and the problems remained.

** Despite telling NRR that the control room was to be protected, "The inspector determined that this has not yet been implemented."

** An access key was misplaced in March and the situation not reviewed by the security committee until half a year later; did not rekey.

"Vaults" that are just normal rooms, "Safes" that are Filing Cabinets

Some facilities describe their storage facilities for unirradiated HEU as "vaults" and their storage vessels as "safes."

For at least some of these facilities, the vaults are normal rooms with normal doors--one in fact is just chain link fence for a door.

And for more than one facility, the so-called "safe" was merely a filing cabinet with a combination lock!

Irradiated Fuel at Very Low Irradiation Levels

It might be believed that for reactors where most of the fuel is in the core, and only a few kilos in storage, that the irradiation of the in-core fuel provides some protection. This is not true for most of the research reactors.

The NRC Staff has already reported to the Commissioners that it is impossible for most research reactors to keep fuel even at the 100 Rem/hour level. A reference calculation is attached to demonstrate how quickly most reactors' fuel drops below that level and how low the irradiation levels really are. It drops below 100 Rem/hour in just 8 hours of shutdown; down to a level of 11 Rem/hour in a week. Many of these facilities only operate a few hours per week; weeks can go by without operation.

Given the Los Alamos estimate of 1.25 hours to complete the theft, doses in the legal range for nuclear workers are all that could be expected for the thieves--particularly if, as is likely, several participate in the theft.

FUEL BUNDLE RADIATION DOSE RATE AFTER SHUTDOWN--
REFERENCE 100 KW RESEARCH REACTOR OPERATED MINIMUM OF
TWO FULL POWER HOURS PER WEEK*

TIME AFTER SHUTDOWN	DOSE RATE PER BUNDLE-REMS/HR
3 HRS	92
1 DAY	33.5
7 DAYS	11
14 DAYS	8.5
21 DAYS	7.3
4 WEEKS	6.5

CALCULATIONS BY DR. ROGER KOHN.

* NORMAL OPERATING LEVEL FOR MANY SUB-MW UNIVERSITY REACTORS

Theft of the Weapons-Grade Uranium on these Campuses Relatively Easy

The equipment for the theft is all at the facilities themselves. The fuel handling tools, the cranes for removal of the core plug (if not a pool reactor), and the electronic equipment useful in bypassing the burglar alarm systems (by looping the signal wire and mimicking any line supervision that might exist). Once done, one could work all night and no one would know it.

These research reactors are made for easy core entry and fuel handling. Students are to do it; core entry must be made often for maintenance; even so simple and common a matter as flux mapping requires removal of shield blocks in those few cores without open pools so that foils can be placed in foil slots. They are designed for entry and fuel removal; unauthorized fuel removal can be readily and easily accomplished. The only barrier in most cases is a burglar alarm system which is child's play to compromise, given the economic value of the material to be stolen, the likely investment a potential thief would put into achieving such material, and the knowledge of people interested to begin with in such nuclear materials.

The unirradiated material would be far easier even to steal; generally in an even simpler location for removal.

The important thing to realize is that weapons-grade uranium is being stored in normal labs at normal universities, with scores of students having access to the facilities and the protection essentially the same as that of the student store or other similar alarmed facility on campus. These facilities where weapons-grade uranium are stored are protected the way any other place on campus is, with perhaps somewhat more sophisticated intrusion alarm systems, but nowhere near the sophistication necessary to prevent their being compromised by someone interested in stealing material for a bomb. Recall also that on site of many of these facilities is half a million or a million dollars worth of bomb-grade uranium, several plutonium sources that could be used in constructing a weapon or as a radiological dispersal weapon, and in some cases, half a million dollars of heavy water in barrels. A thief could make quite a lot financially from such a theft; a thief interested in making a weapon would have even more incentive. Primitive matters such as bypassing alarm wires would be a piece of cake to such a thief.

These reactors would have three places where fuel is stored: lightly irradiated fuel in core, readily retrievable; lightly irradiated fuel in storage, often in holes in the floor near the reactor with plugs easily removed or in storage pools; and fresh fuel, either in a back storage room used for other storage or in a storage pool. One could get in and out without detection without problem, leaving with many kilos of weapons material; even if detected, the campus police officers are unlikely to be able to deal effectively with determined adversaries prepared to steal weapons material to make a clandestine fission explosive.

Stealing 4900 grams of the HEU as bad as 5100 grams: "Formula Quantity" Wrong

As Dr. Taylor has indicated, theft of kilogram quantities of HEU would be of grave concern. Given the large reduction in HEU quantities needed for an implosion device compared to the standard references to minimum quantities at normal density, unprotected and underprotected HEU at university reactors in the kilogram range pose major safeguards and proliferation hazards.

Far more than a detection and reporting ability is needed, but some university reactor personnel believe all they must be able to do is let someone know the HEU has been stolen sometime after the fact. This is a terribly dagerous attitude and invites theft of extraordinarily dangerous material.

CONCLUSION

The Commission's Policy on converting research reactors to LEU to the maximum extent possible is highly responsible, internationally acclaimed, and the right thing to do.

There are no technical barriers to such conversion. "The maximum extent possible" is convert all of them--with the possible exception of MIT and U of Mo-Columbia, after careful scrutiny.

The proposed exemption for "lifetime cores" is an artifice that would permit lifetime possession of HEU, in reactors where the radioactivity level is far below anything that could be considered "self-protecting." It would gut the Commission's Policy and throw a monkey-wrench into attempts to convert foreign reactors, because they would see we were only converting 3-5 of our own reactors, exempting the rest.

Most research reactors cannot get anywhere near 100 rem/hour "self-protection" levels for fuel bundles.

The 5000 grams "formula quantity" is not founded in fact; reactors with less than that quantity are leaving their kilogram amounts of HEU almost entirely unprotected.

HEU at college campuses is generally protected almost entirely by a burglar alarm system tied into a college campus. These facilities are protected the way other facilities are on campus, and a determined thief interested in weapons-grade uranium would have little problem successfully stealing the material, probably without detection.

Security is very lax at these facilities; the danger of HEU theft is not taken seriously; extraordinary security violations are routine, with correction slow or non-existent; relaxation any further of security requirements goes in the wrong direction. Security for weapons-grade materials should be upgraded, both as incentive for conversion and because if HEU is to be possessed, security must be adequate to prevent its theft by a determined group intent on acquiring a nuclear weapon.

The Commission should enforce its August 1982 Policy. University and other research reactors in this country should be converted to low enriched fuels, rapidly and diligently. Excuses from the licensees should not prevent proceeding on an important public policy course. Theft of HEU would have consequences of a most grave sort to the international community.

Conversion of research reactors to LEU is a sweet, technical fix that meets everyone's needs. The research reactor community can do all that it wishes to do with its reactors; the non-proliferation community can breathe easier that weapons-grade uranium here or abroad will not fall into the hands of groups or nations intent on acquiring atomic weapons.

This is one of the few U.S. nonproliferation initiatives (reduced enrichement) with wide international and domestic support. To "enforce" the Commission's Policy by exempting virtually all research reactors in this country from it, as proposed by the research reactor licensees, would be a very grave mistake and could result in a serious setback to nonproliferation efforts.

The consequences would be very serious were any of the HEU at these reactors stolen or diverted. The solution is simple: let the reactors keep operating, but with fuel that if stolen is no proliferation threat. A sweet, technical, inexpensive solution to an important aspect of one 6f the most important issues of our time.

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

DISCUSSION OF INTERNATIONAL IMPLICATIONS OF CONVERSION OF DOMESTIC RESEARCH REACTORS TO LEU USE

PUBLIC MEETING

Room 1130
1717 H Street, N. W.
Washington, D. C.

Friday, January 27, 1984

Pursuant to Notice, the Commission met in open session at 2:55 o'clock, p.m.

COMMISSIONERS PRESENT:

NUNZIO PALLADINO, Chairman of the Commission
VICTOR GILINSKY, Commissioner
THOMAS ROBERTS, Commissioner
JAMES ASSELSTINE, Commissioner
FREDERICK BERNTHAL, Commissioner

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

J. DEVINE, DOS
J. KANE,DOE
A. TURRENTINE, ACDA
S. CHILK
S. TRUBATCH

AUDIENCE SPEAKER:

J. YOUNG, DOE

DISCLAIMER

This is an unofficial transcript of a meeting of the United States Nuclear Regulatory Commission held on Friday, January 27, 1984, in the Commission's offices at 1717 H Street, N. W., Washington, D. C. The meeting was open to public attendance and observation. This transcript has not been reviewed, corrected or edited and it may contain inaccuracies.

The transcript is intended solely for general information purposes. As provided by 10 CFR 9.103, it is not part of the formal or informal record of decision of the matters discussed. Expressions of opinion in this transcript do not necessarily reflect final determinations or beliefs. No pleading or other paper may be filed with the Commission in any proceeding as the result of or addressed to any statement or argument contained herein, except as the Commission may authorize.

PROCEEDINGS

CHAIRMAN PALLADINO: Good afternoon, ladies and gentlemen. The Commission is meeting in this session with representatives of the Department of State to be briefed on some of the international implications of conversion of domestic research reactors to low enriched uranium or LEU.

The meeting will be in two parts. First, we will have a short briefing in an open session. Following that, members of the NRC and the Department of State will move to my conference room to continue classified pursuit of the remaining issues in closed session.

On behalf of the Commission, I want to extend appreciate to our visitors from the Department of State for taking their time to appear before us and also their patience due to the delay we encountered.

I am sure that the information that you will present to us will be very helpful to the Commission in further deliberations on this matter.

At this point, I should also announce that the Commission has decided to postpone the closed meeting with the staff regarding physical security at domestic research reactors and schedule it for another time to be announced.

Do any of my fellow Commissioners have opening remarks?

(No response.)

CHAIRMAN PALLADINO: If not, then let me turn the meeting over to Mr. DEVINE.

MR. DEVINE: Thank you, Mr. Chairman. Let me ask my two colleagues here to introduce themselves.

MR. TURRENTINE: I'm Archles Turrentine from the Arms Control and Disarmament Agency.

MR. KANE: James Kane, Department of Energy.

CHAIRMAN PALLADINO: Okay, thank you.

MR. DEVINE: I have a prepared statement I would like to go through if I may, Mr. Chairman.

The Executive Branch is fully committed to implementation of the goals of the Reduced Enrichment for Research and Test Reactors program. The Department of State, along with the Arms Control and Disarmament Agency, strongly supported the Department of Energy in establishing this program in the late 1970's because of the potential contribution of the RERTR program to the conduct of U. S. non-proliferation policy.

The program was started in 1978 to support the U. S. initiative to reduce the proliferation potential and the threat of nuclear terrorism associated with international commerce in highly enriched uranium. The program goal is to develop the technology needed for conversion of research and test reactors to the use of low enriched fuels at levels of less than 20 percent.

Most of the work is carried on at the Argonne National Laboratory under DOE's aegis. Since 1978, similar programs for development of reduced enrichment fuel have also been established in a number of countries including France, the FRG, Japan, Canada, and the United Kingdom. Programs for studying reactor conversions are in progress in 19 other countries. The International Atomic Energy Agency has established a small program, the purpose of which is the coordination and promotion of education activities relating to the overall reduced enrichment effort, particularly for developing countries.

Cooperation among participating governments has been outstanding to date. The technical program to develop and demonstrate high density fuels for research reactors is going very well. Aluminide, oxide, and silicide plate-type fuels have been developed by DOE and by the commercial manufacturers -- NUKEM in the Federal Republic of Germany, and CERCA in France.

In the United States, zirconium hydride rod-type fuels have been developed by GA Technologies, and Babcock and Wilcox has established the capability to manufacture plate-type fuel elements.

Canada, Argentine, Denmark, the U.K., Japan, and the USSR are also developing and evaluating LEU fuels technology. The development of very high uranium density, 20 percent enriched silicide fuel may permit most U.S.-supplied foreign research and test reactors to convert to such fuel without geometry change of the elements, and without significant neutronic penalty.

An important aspect of the U.S. RERTR program is Argonne's involvement with operators of foreign research reactors to examine the possibility of timely conversion to use of lower enrichment fuels and with operators of U.S. reactors in testing and evaluating the technology.

A whole-core demonstration in the Ford nuclear reactor at the University of Michigan is nearly complete and a second whole-core demonstration with high density silicide fuel is being planned in DOE's ORR reactor at Oak Ridge. Joint studies on conversion feasibility are ongoing between Argonne and reactor operators in Austria, Japan, Romania, Sweden, Netherlands, Argentina, Australia, Chile, Turkey, Greece, the U.K., and Denmark.

Also the following countries are testing, or will test in the near future, prototype LEU fuel elements in their reactors: Argentina, Austria, Brazil, Canada, Denmark, France, the Federal Republic of Germany, Greece, Japan, the United Kingdom, the Netherlands, Romania, Sweden, Switzerland, Turkey, and the United States.

International meetings are sponsored annually by the IAEA, the U. S., and other host countries for information exchange on the status of R & D within the RERTR and related programs and on research reactor operation and use. The most recent was near Tokyo in October of last year. The IAEA, with multi-national participation, including the U. S., has compiled and issued a guidebook on the principal aspects of research reactor core conversion. Two additional guidebooks address the conversion of heavy-water research reactors to LEU fuel and the safety and licensing aspects of core conversions.

The program is still largely in the testing phase.

Only two reactors in the non-Communist world actually have a full core of low enriched fuel and have been licensed to use it. These are the Osiris reactor in France and the Ford nuclear reactor in the United States.

Further tests on LEU fuels with high uranium density, including a full-core demonstration with silicide fuel, are required. In addition, safety analyses are required and related licensing issues need to be resolved.

Reprocessing of silicide and other LEU fuel is a very important issue for LEU conversions and also needs to be resolved. For example, in the major user countries, license amendments will not be issued to reactor operators for use of new fuel alternatives unless there is documentary evidence that the U. S. agrees to take back LEU fuel for reprocessing or other disposition, as has been done to date for spent HEU fuels.

Credit for recovered uranium is an important economic consideration for the reactor operator. Our experiments on reprocessing advanced LEU fuels within DOE facilities have been completed successfully by DOE at Savannah River and DOE is currently assessing the overall LEU reprocessing issue.

The testing phase needs to continue and most of the new low enriched fuels will not be ready for use until the 1985 to 1989 time frame. During that period, we should see the new LEU fuels being accepted routinely as a substitute for the current HEU reloads -- the ultimate goal of the program.

This brings me to an important characteristic of the

RERTR program which I mentioned a few minutes ago but which merits further elaboration because I believe it has been a critical factor in the development and testing phases of the program. This is the spirit of willing cooperation which has prevailed throughout the course of the program. I believe it is most important that this cooperative spirit be maintained as we approach the reactor conversion stage. There are a number of factors which have fostered this cooperative atmosphere, not the least of which has been the outstanding efforts of the Argonne program managers, scientists, and technicians.

Another key contributing factor has been the commitment of the United States to be a reliable supplier of HEU in the period prior to conversion to the use of LEU. We have pursued a system of voluntary cooperation without arbitrary deadlines. Our processing of HEU license applications has been speeded up over the last four years. All of our trading partners, to whom we can export HEU under the Atomic Energy Act, have obtained adequate and timely supplies. With the cooperation of the NRC, we trust we will be able to continue this approach. In return, we expect continued cooperation on conversion studies and timely conversion when feasible.

With respect to U.S. HEU policy in general, there is unanimous agreement among foreign governments and programs that reduced trade flows in HEU could help reduce the risks of nuclear proliferation and terrorism. However, their support for reducing commerce in HEU is conditioned by the obvious necessity that the new fuel should not significantly affect the safety, performance, licensibility, and economics of the research reactors.

With adequate and continued U. S. commitment to meet fuel development and demonstration schedules, including full-core testing, resolution of the LEU reprocessing issue and continued international participation, and with no undue delay in the licensing procedures, the RERTR program should allow for conversion of most research reactors to use of LEU fuel by the end of this decade.

The concerns and purposes behind our program abroad, of course, are linked to our overall non-proliferation efforts, and this effort will continue whatever the decision may be in respect to the domestic program.

The proposed rule for conversion of domestic research and test reactors, as I understand it, calls for replacement of spent HEU fuel with low enriched fuel "if such action would be technically feasible with existing fuel technology at the time of refueling and unless the licensee shows that the unique purposes of the project could not be achieved without using HEU fuel."

I would like to point out that this proposal would be compatible with the criteria used for establishing conversion feasibility and schedules in cooperation with foreign reactor operators.

As the period for actual conversion approaches, a few foreign reactor operators have expressed an interest in whether the U. S. is applying the same guidelines domestically and have asked what steps the U. S. is taking to convert domestic research reactors. The actions of the NRC on this matter can be expected to have some marginal effect on our future negotiations with foreign reactor operators on the need and timing for converting their reactors.

In considering measures which will encourage conversion of research reactors, our international experience with RERTR participants has underscored the importance of being sensitive to licensing and funding issues. This includes trying to accommodate needs for HEU fuel during the transition period rather than trying to force the pace to the point of creating resistance.

I hope the Executive Branch and the NRC can work together on the RERTR program which we regard as a positive contribution to our long-term non-proliferation objectives.

CHAIRMAN PALLADINO: Thank you, Mr. Devine.

MR. DEVINE: I think Mr. Kane has an additional short statement.

CHAIRMAN PALLADINO: All right, Mr. Kane.

MR. KANE: Would you like me to proceed at this time?

CHAIRMAN PALLADINO: Yes, go ahead.

MR. KANE: Thank you, members of the Commission, for allowing DOE to present its viewpoints.

I will deal mainly with topic 5 and 6 in Mr. Dircks letter to Ambassador Malone. I'm not going to go over all the topics that Mr. Devine has just covered. I also brought a small packet of more detailed data which I will leave with your staff, if you want me to do that.

CHAIRMAN PALLADINO: Okay.

MR. KANE: I would like to point out, first, that the Department is involved in three different activities related to this RERTR program. One is the development and demonstration, as mentioned by Mr. Devine, of the low enrichment fuels and assuring their commercial availability. That's being done mostly at the Argonne National Laboratory and under the jurisdiction of the Assistant Secretary for Nuclear Energy.

The second area where we are involved is our restudying of reprocessing of the spent low enrichment fuels in DOE facilities. That is being done under the jurisdiction of the Assistant Secretary for Defense Programs. Now, I will give you a status report on each of these two efforts.

Finally, our involvement in the Department Energy is because we do operate research and test reactors. So that's our third area of involvement -- as operators of these reactors for a variety of purposes, and let me take them in that order.

As was just said, the process on low power low enrichment fuels, LEU fuel appropriate for conversion of certain of these low power reactors has been developed and verified by a full-core demonstration at the Ford nuclear reactor at the University of Michigan, and we discussed that last time I was here. I'll say nothing further on that as you actually had the operator on that reactor here as a witness.

The second point, an LEU fuel which is a U3SI -- a high density fuel -- suitable for conversion of some -- I'm not going to speculate just how many, but medium to high power research reactors -- is now under development. Several core loads of this LEU fuel will be procured in fiscal years 1984 and 1985 for use in a demonstration of an equilibrium LEU cycle in DOE's 30 megawatt Oakridge reactor.

Complete qualification is expected in the 1988 to 1999 time frame. The technical aspects of this program seem to be going very well. I have no further comments on that other than the success, like any other program, is dependent on stable funding -- and that is not a plea for additional funding. The program is not funding limited but, clearly, it has to be stable in the future. So that's the status of the fuel development program.

The second point I said I would cover briefly is the reprocessing of spent low enrichment fuels. That's topic 6 on Mr. Dircks' letter to Mr. Malone.

The government policy on this for HEU fuels is very clear. Since 1968, we've had a policy of accepting fuels providing they were produced or enriched in the United States and it uses defense program facilities, specifically those either at Idaho, which is the Idaho chemical processing plant, or those at the Savannah River plant in South Carolina. The processing, to date, of course, has only been on the high enrichment fuels.

In fiscal year 1982, work at the Savannah River plant to assess the low enrichment uranium processing existing facilities with modifications in cost -- that was the problem -- to assess. Could we do it in existing facilities and, if so, what would be the modifications and the cost from those modifications.

COMMISSIONER GILINSKY: Can I stop you for a moment?

MR. KANE: Sure.

COMMISSIONER GILINSKY: Do you also accept fuel of that type from U. S. reactors -- universities and so on?

MR. KANE: Yes.

COMMISSIONER GILINSKY: So they ship stuff to you for reprocessing as well?

MR. KANE: That's right. Reprocessing of the uranium aluminide ones. The trigger ones, we have no reprocessing for those.

CHAIRMAN PALLADINO: What?

MR. KANE: We have no reprocessing facilities for the trigger-type fuel elements -- uranium zirconium hydride.

COMMISSIONER GILINSKY: Do you accept the spent fuel from the university reactors?

MR. KANE: Yes, that's correct.

COMMISSIONER GILINSKY: Can they unload whatever spent fuel they have?

MR. KANE. That's right, and we give them credit for the unburned fuel.

COMMISSIONER GILINSKY: I don't know whether these are just sort of clerical or bureaucratic difficulties, but there are a lot of complaints about getting all that accomplished, and I don't know whether they are complaints against DOE or NRC, or whatever, but they claim the system doesn't work smoothly.

MR. KANE: I really can't comment on how smoothly it works. It's probably fund-limited and we do this to a certain amount of reactors every year and whether we keep everybody happy or not, I don't know. Would you like me to explore that further?

COMMISSIONER GILINSKY: You mean after the meeting? Is there something you wanted to tell us?

MR. KANE: I really don't know. I have some people with me in the audience. Would you like me to ask them? A Dr. Harry Young is here with me, today, and he runs this university uranium program.

COMMISSIONER GILINSKY: Yes, I would like to hear about that.

MR. KANE: Harry, would you care to comment on that?

CHAIRMAN PALLADINO: And also what you do with trigger-type fuel.

MR. KANE: Yes. Harry is responsible for the university fuel program.

DR. YOUNG: If I understand the question --

CHAIRMAN PALLADINO: Would you give your name and affiliation.

DR. YOUNG: My name is Harold Young and I'm with the

Office of Energy Research in the University Programs. I manage the university reactor fuel assistance program and reactor sharing. As part of that, we provide funding for the fabrication fuel that goes to university reactors.

Since, I think it was about, 1978, fuel has been provided to these reactors through a cost-plus-fee contractor. Prior to that, funding was provided to the universities and they went out and bid for their own fuel.

COMMISSIONER GILINSKY: You paid the entire cost?

DR. YOUNG: There is no longer a commercial supplier. There is only one supplier of fuel in the country.

COMMISSIONER GILINSKY: Do you supply all the fuel to the university reactors?

DR. YOUNG: Yes. This is government-owned fuel. It's loaned. It's provided on a loaned basis. They do not own it. Title is retained by the government, the Department of Energy.

COMMISSIONER GILINSKY: Well, let's see. So when we're talking about switching over, it's just a matter of you providing different fuel?

DR. YOUNG: It's a matter of us providing the cost for the fabrication of this fuel and, of course, the acceptance of spent fuel that comes back.

COMMISSIONER GILINSKY: I guess I'm a little unclear. Suppose Chairman Palladino's colleagues at Penn State have got some fuel they want to get off campus. can they just call you up and arrange for it to be removed?

DR. YOUNG: No. Our funding resources have not been adequate over the past I'd say six or eight years to pay for the cost of shipping fuel. Legally, we can provide that assistance, but the universities have preferred to see whatever funding we had to go to cover the cost of fabrication of new fuel.

COMMISSIONER GILINSKY: So that stuff is sitting around there. But what if they --

DR. YOUNG: The spent fuel?

COMMISSIONER GILINSKY: Yes.

DR. YOUNG: Well, they have been shipping it. See, the reactors that are the most active are those plate-type reactors with about one megawatt above power.

COMMISSIONER GILINSKY: Yes, and what happens to that stuff?

DR. YOUNG: Well, they ship it probably every two to four years, depending on how much accumulates.

COMMISSIONER GILINSKY: At their expense?

DR. YOUNG: At their expense. They have been doing it the last few years at their own expense.

COMMISSIONER GILINSKY: And where does it go?

CHAIRMAN PALLADINO: Wait a minute. At their expense for shipping, is that right?

DR. YOUNG: The university for shipping, that's right.

COMMISSIONER GILINSKY: If they pay for it, do you accept it?

DR. YOUNG: It goes to either Savannah River or Idaho.

COMMISSIONER GILINSKY: Is there any question about it being accepted?

DR. YOUNG: No.

COMMISSIONER GILINSKY: So it's just a matter of the transportation costs.

DR. YOUNG: It's a matter of the transportation costs and the licensing in that process.

CHAIRMAN PALLADINO: Does that include acceptance of trigger-type fuel -- zirconium hydride?

DR. YOUNG: Yes. The trigger fuel is only stored. That goes to Idaho and it's simply just stored at the present time.

CHAIRMAN PALLADINO: You don't process it.

COMMISSIONER GILINSKY: Let me just get back to an earlier point about the supply of this fuel. You supply the funds for that fuel or you actually supply the fuel to the university? Does it come in a government vehicle?

DR. YOUNG: No. We provide the cost of fabrication.

COMMISSIONER GILINSKY: But the fuel belongs to you?

DR. YOUNG: The fuel belongs to us, and it's provided on a loan basis and then returned.

CHAIRMAN PALLADINO: Does the university pay for the shipment to its site?

DR. YOUNG: Well, as a matter of fact, they do.

COMMISSIONER GILINSKY: But that must not be so expensive, at least on the way in.

CHAIRMAN PALLADINO: I was just trying to see what the parallel was on both ends.

COMMISSIONER GILINSKY: But it's your fuel. You paid for the fabrication and so it still seems to me that switching over is really almost a DOE decision. If you start supplying low enriched fuel, everybody will switch over.

CHAIRMAN PALLADINO: I presume they still have to evaluate --

COMMISSIONER GILINSKY: Oh, sure. We've got to work out the details but that can all be done. I mean, that's what all these nuclear engineers are for. Why is there anything more to it than that?

MR. KANE: So far, the fuels that are developed and available are only suitable for a small fraction of the research reactors. Those that can get by with a fuel element density of about three or less.

COMMISSIONER GILINSKY: Well, that isn't quite right. It is without any change whatsoever.

MR. KANE: Without any modification.

COMMISSIONER GILINSKY: But, if you're willing to make some modifications, then almost all of them can be changed over. Do you disagree with that?

MR. KANE: I think at the top end of the spectrum, for instance --

COMMISSIONER GILINSKY: That's why I said almost all of them.

MR. KANE: Almost all. Almost all is quite a large fraction in numbers. Certainly, the MITR, the one at Missouri and the HFIR, which is ours, the ATR, which is ours, they are up in a few --

COMMISSIONER GILINSKY: I was just talking about the university reactors. I think there are just two.

MR. KANE: There are two.

COMMISSIONER GILINSKY: Right. That's what I had in mind, precisely.

I guess what strikes me that what I thought were 24 decisions sound really like they could be one decision.

CHAIRMAN PALLADINO: I guess I don't understand what it takes, then, to negotiate changes that can accommodate the existing fuel. Those changes, I presume, would be the universities to make, right?

MR. KANE: That's correct, yes.

COMMISSIONER GILINSKY: But, if you simply said that from now on, or from 1980 or whatever it is, you're going to be supplying LEU and between now and then people have got to sit down and make whatever calculation and NRC has got to conduct its reviews and so on, and suppose we had a task force to push all this through with a program manager, it would all get done.

MR. KANE: I think everything you said except the "simply" part of it. I think the technical aspects of just substituting low enrichment fuel for high enrichment fuel look very promising to me, like that is going to be the simplifier.

As I said in my previous testimony here, many of these universities' reactors are hanging by a thread, in some ways, and it's not simple to them to spend a few hundred thousand dollars on engineering safety analyses and those kinds that I think they will have to do before you will allow them to go ahead and just substitute the low enrichment fuel.

CHAIRMAN PALLADINO: Some of these reactors, I gather, also have life-time fuel --

MR. KANE: That's correct.

CHAIRMAN PALLADINO: -- so you'd have to work out something on that.

COMMISSIONER GILINSKY: Does that fuel belong to DOE?

MR. KANE: Yes.

COMMISSIONER GILINSKY: So it's just your fuel. So you take it back and do something else with it.

MR. KANE: Again, the cost of replacing the fuel element -- in that case, there would be a single one-time process, yes.

COMMISSIONER GILINSKY: On the business of the analyses, sure, people would have to do some work but, my God, what an opportunity to learn things. These reactors are basically there to train nuclear engineers. How better could they be trained than redesigning those reactors? There's not that much to it, either.

MR. KANE: I would debate that issue with you. If you were a dean of a university, you've got to weigh that cost versus some other things you could do with the money, and I'm not going to debate that because I'm not a university person.

COMMISSIONER GILINSKY: I, frankly, think it wouldn't be such a bad idea if NRC supported some of that work.

CHAIRMAN PALLADINO: You mean supported the conversion.

COMMISSIONER GILINSKY: Supported the analyses or some of the analyses and so on. Even though that may be seen as confusing some of our roles, that doesn't make me uncomfortable.

CHAIRMAN PALLADINO: I wouldn't dismiss so casually the business of costs to the university because it could make the difference between that reactor staying in business and not staying in business.

COMMISSIONER GILINSKY: Yes, but what it looks like is that the fuel cost is really the DOE -- one way or another, it's a DOE cost. DOE supplies the fuel.

CHAIRMAN PALLADINO: I'm thinking of the other conversion costs.

COMMISSIONER GILINSKY: And the conversion costs, I wonder if they haven't been overdone. What we're really talking about is reanalyses and it's not as if we're dealing with a thousand megawatt reactor, we've got some plates in a pool of water.

CHAIRMAN PALLADINO: Let me make an observation. I understand that --

COMMISSIONER GILINSKY: I mean, it's not that big a deal.

CHAIRMAN PALLADINO: I understand Mr. Devine has to be somewhere else by 4:00.

MR. DEVINE: Right.

CHAIRMAN PALLADINO: I think a point has been made and maybe we ought to go on to other items. I think there's a related question I was going to ask Mr. Devine and maybe between the two of you you can answer.

I've heard that foreign countries are questioning whether or not the same arrangements can be made with regard to LEU fuel as is with HEU fuel, particularly with our taking fuel back if it's our fuel. Is this a serious problem? Are arrangements possible to overcome it?

MR. DEVINE: Well, as I said in my statement, it is very important to these foreign operators. We've been quizzed on that on a number of occasions and I think DOE is exerting its best effort to resolve whatever --

MR. KANE: I was about to get to that.

CHAIRMAN PALLADINO: Oh, I'm sorry. Go ahead. Why don't we let you continue.

MR. KANE: Let me continue. I was on to the second point which is this reprocessing point. The government policy for HEU fuel since 1968 has been we will accept all fuels produced or enriched in the United States, which includes a great deal of those that are used in foreign reactors, and this policy, by the way, was re-extended through 1988. So it is our current policy and through 1988 to reprocess foreign fuels, domestic, just as long as they are produced or enriched in the United States.

The only question, now, is will we transfer this policy to low enriched fuels, and we're looking at that. We have looked, so far, on what would be the affect on the defense program facilities. That study is complete and it can be done in existing facilities. Naturally, dissolving a silicide is not exactly the same as dissolving an aluminide or an oxide, but it can be done with appropriate flow-sheet modifications, and the costs are not really accurately known so we can obtain full cost recovery, but they don't look exorbitant.

The first look indicates that reprocessing is feasible and it's encouraging and we should have an estimate of the cost and the impact on DP facilities. That is the other thing that could conceivably sway us one way or another on extending this policy to low enriched fuels.

We should have that for you next fall or early winter, or something like that. In other words, the start of fiscal year 1985, we should announce a commitment to accept or not to accept, depending on how the decision comes out, the low enrichment fuels, which would then be the same as the current one on high enrichment fuels.

CHAIRMAN PALLADINO: But, if you did not accept it, then that could have a severe impact --

MR. KANE: Severe impact, yes. I don't want to speculate on the probability. I think I'm encouraging that the chances are pretty good that we will extend this to low enrichment fuel. I can't promise you at this time.

The final point I was going to make has to do with our operation of these reactors and, if he's in a hurry, maybe you would like me to delay that. We are operators of a number of these reactors and, if he's in a hurry, maybe you would like to take him first. It's up to you, Mr. Chairman.

CHAIRMAN PALLADINO: Well, I wanted to cover the items we can cover in the open meeting.

MR. KANE: Okay. It will just take me very briefly.

CHAIRMAN PALLADINO: All right.

MR. KANE: We are supportive of the goals of this nuclear non-proliferation act. That's a department position. To clarifying exactly what we're doing and what we're not doing, I've told you two things we're clearly doing but, other than the demonstration activities that I told you about in the ORR, we're not currently proceeding with any conversions of our reactors. There's no plans underway now to convert, and our view is -- rather than some kind of cursory studies.

The word that was used in the letter to Ambassador Malone from Mr. Dircks spoke of a parallel program. We don't have a parallel program. We're taking a sequential viewpoint to this. If ORR test and development proves out, then we'll look at the next step, but we're not going ahead and planning to convert on the assumption that's it's going to work. I think it is going to work, but there is no plan, right now, to convert our reactors. We're waiting the outcome of the ORR demonstration.

CHAIRMAN PALLADINO: But if the silicide fuel works, then presumably you would develop plans?

MR. KANE: Right. If the results from the ORR are positive, we'll consider conversion of a research and test reactor, and here's kind of the following conditions:

The LEU fuel must be proven technical suitable and commercial available. It looks like that -- again, I'm being optimistic -- probably will happen.

We'll use up our supply of HEU cores prior to conversion. Since most of our reactors -- talking just about the DOE reactors, now -- go through quite a few cores, this shouldn't require much of a delay except maybe for one or two reactors.

Finally, the technical -- this is a tough one -- the technical and fiscal impact on the programs using reactors must be acceptable. Now, I struggled along time before using that word "acceptable" because it's open to question, but you have to realize that most of these reactors in the DOE were built for some very specific purpose. It's like obtaining a very high neutron flux, for instance, for experiments.

If we were to sacrifice some fraction of that -- I'm not going to try to say what fraction would be acceptable. That's something we'll have to face when the time comes, but that's our current plans, right now.

To view what happens in the ORR demonstration; to use up the existing cores in those reactors which have a supply of them. In most cases -- reactors like HFIR and HFBR burn up a lot of cores in a year. They burn up a lot of fuel. So that's not a long-time impact for those two, at least. Then we will look at the technical and fiscal impact on the programs that use these reactors.

All the reactors that I am responsible for are research reactors. They are involved in basic science. I think that's enough. I will be pleased to answer any questions you have.

CHAIRMAN PALLADINO: All right. Thank you. While the Commissioners are thinking of possible questions, does the representative from ACDA have any comments?

MR. TORRENTINE: No, Mr. Chairman, I have no statement.

COMMISSIONER GILINSKY: Can I ask one brief question. We were told that many of the university reactors originally operated on LEU or were designed for that sort of fuel and then were switched over to HEU, does that --

MR. KANE: I will have to defer this to Harry, again. I'm sorry, Mr. Commissioner. Harry, can you help on that?

COMMISSIONER GILINSKY: Would you know about that?

DR. YOUNG: I don't know the details. I've heard that but I'm not familiar with the background or history on it.

CHAIRMAN PALLADINO: Well, most of the early university research reactors were really built on the MTR fuel element concept and so I think they were primarily high enriched uranium. When the opportunities came for the zirconium hydride fuel, a number of universities took advantage of that for a variety of reasons, including flexibility in operation -- pulsing capability.

An other questions for our colleagues in the open meeting?

COMMISSIONER ASSELSTINE: Just a couple. You mentioned, in closing, the problems and the effort that you go through in looking at the DOE reactors. It doesn't sound like that is materially different than what would need to be done for the research reactors. In essence, that the reactor could still perform its test programs and its capabilities with the low enriched fuel. Are there any particular technical problems or difficulties that you perceive?

MR. KANE: I am really not an expert in this, Mr. Commissioner. Just basing it on the density of the uranium -- that's a very crude measure, but maybe it's good enough for this kind of an answer -- it looks like there shouldn't be any enormously difficult problems except for two or three of them that are very close to the edge on this silicide fuel.

Now, you understand that we have a large investment in some of these reactors. Just look at it from the science viewpoint. You're taking out low density stuff. You're putting in much more U-238. That's bound to affect the hardness of the spectrum in some of the subtle parts of the reactor and whether the affect will be trivial or whether it will be major, I think only a more detailed analysis can tell.

I'm attempted to give you a glib and maybe wrong answer that for most of the reactors it will not be a major change. But, for some of them at the high end of the fuel density, I worry.

COMMISSIONER ASSELSTINE: Back to the university reactors, it really sounds like the problem there, with the exception of MIT and the University of Missouri reactors, really is just one of money. For all intents and purposes, it's coming up with the money to replace the fuel and to pay for whatever changes analysis needs to be made, with the possible exception of assuring that there is a stable licensing process for handling any license amendments that would be required.

MR. KANE: I think the experience of the foreign nuclear reactors bears out your statement.

COMMISSIONER ASSELSTINE: I gather that, even in the aggregate, when you look at the total amount of money involved, it's not real great, certainly in comparison with other nuclear programs, but when you get down to university level, it maybe something that causes a good deal of difficulty there.

MR. KANE: Again, I agree with you.

COMMISSIONER ASSELSTINE: The last question I had, Jim, had to do with your statement that as far as other countries were concerned, at least one marginal element was that progress was being made here. The sense I had, from some of the foreign visitors that have come through recently is that in some cases, at least, it's more than marginal but that they're looking fairly closely at what kind of progress is being made in this country to reduce enrichment levels. Do you have the same kind of sense?

MR. DEVINE: Certainly, they have not raised it in any formal fashion to that degree. A few of them have asked us about it but it has not become as important an issue as the return for reprocessing issue, for example.

CHAIRMAN PALLADINO: Any other questions.

(No response.)

CHAIRMAN PALLADINO: Thank you, gentlemen. I suggest, now, that we discontinue this part of the meeting as a public meeting and adjourn to our conference room on the other side of the hall and continue with our classified meeting.

(Whereupon, the foregoing meeting was adjourned at 3:30 o'clock, p.m., to reconvene in closed session.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the Commission in the matter of: Discussion of International Implications of Conversion of Domestic Research Reactors to LEU Use, held on January 27, 1984, at 1717 H Street, N. W., Washington, D. C., were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Elizabeth Ann Tipton
Official Reporter (typed)

Elizabeth Ann Tipton
Official Reporter (Signature)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

DISCUSSION OF LEU/HEU GUIDANCE

PUBLIC MEETING

Nuclear Regulatory Commission
Room 1130
1717 H Street, N. W.
Washington, D. C.

Monday, February 6, 1984

The Commission convened, pursuant to notice, at 3:15 p.m.

COMMISSIONERS PRESENT:

NUNZIO PALLADINO, Chairman of the Commission
VICTOR GILINSKY, Commissioner
THOMAS ROBERTS, Commissioner
JAMES ASSELSTINE, Commissioner
FREDERICK BERNTHAL, Commissioner

STAFF AND PRESENTERS SEATED AT COMMISSION TABLE:

S. CHILK
R. MALLORY
D. RATHBUN
W. DIRCKS
R. MINOGUE
J. DAVIS
C. ONG

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DISCLAIMER

This is an unofficial transcript of a meeting of the United States Nuclear Regulatory Commission held on Monday, February 6, 1984, commencing at 3:15 p.m., in the Commission's offices in Room 1130 at 1717 H Street, N. W., Washington, D. C. The meeting was open to public attendance and observation. This transcript has not been reviewed, corrected or edited and it may contain inaccuracies.

The transcript is intended solely for general informational purposes. As provided by 10 CFR 9.103, it is not part of the formal or informal record of decision of the matters discussed. Expressions of opinion in this transcript do not necessarily reflect final determinations or beliefs. No pleading or other paper may be filed with the Commission in any proceeding as the result of or addressed to any statement or argument contained herein, except as the Commission may authorize.

PROCEEDINGS

CHAIRMAN PALLADINO: Good afternoon, ladies and gentlemen.

The Commission is meeting today to discuss guidance to be provided to the staff relative to the reduction in the use of high enriched uranium at domestic research reactors.

As a basis for discussion, we could use the draft guidance prepared by the staff dated February 1st, 1984. If that is acceptable, we would first have the staff walk us through the draft language and then we could see what comments, if any, OPE or OGC might have.

Do any of my fellow Commissioners have any opening remarks before we begin?

COMMISSIONER GILINSKY: I am ready to be walked through.

(Laughter.)

CHAIRMAN PALLADINO: All right. Then let me turn this over to Mr. Dircks.

MR. DIRCKS: We don't want to walk through it too much. What we thought we would do is explain the highlights and compare it with SRM that the Commission sent us on June 21.

CHAIRMAN PALLADINO: That would be very good.

MR. DIRCKS: Essentially the draft SRM that we provided the Commission on February 3rd takes the material that was contained in the June 21st memo. It essentially adopts that but expands it to provide the flexibility of the Director of NRR to deal with licensing questions. That is all that is essentially contained in that draft that we sent you.

The other issue that is contained in that draft that we sent down on February 3rd is the issue of providing interim upgrade of security measures at domestic research reactors and there are about five points in that area that we wish to bring to the Commission's attention and you have already heard the details on those five points.

Bob Minogue can go further into the background of the two memos if there is a desire to do so.

CHAIRMAN PALLADINO: I was interested in what you were adding in Part A to the staff requirements memo we had in June.

CHAIRMAN PALLADINO: All right.

Bob, do you want to comment?

MR. MINOGUE: Yes. Let me answer you, Mr. Chairman. I think the best way to do it is to focus on the high spots. The whole draft memorandum basically implements the guidance of June 21st. So it is not a different approach.

Some of the points that are included in Section

A, and I will take them up in the order in which they occur, which may not be necessarily the completely logical order, but, first, there is a recognition of a question that had been raised by many of the people who have commented to you in the several meetings that we have had of the need to assure that any additional licensing steps that are required reflect a real need.

There is a perception, which is not based on any extensive studies or in fact on any studies at all by the staff, that probably for a large number of the reactors the modification involved in changing the fuel would not have any significant effect on the safety of the system.

The proposal that is in this guidance would be to assess that on a generic basis. This would be a task that NRR would undertake. It clearly could not be done within the time frame of going out with a proposed rule. So the presumption is that it would be done during the beginning or very soon but continuing on into the comment period to do a generic assessment both in terms of trying to identify classes of reactors that would have a commonality of the change and then assessing the safety significance of the changes that might affect the coolability of the configuration from a change in fuel.

COMMISSIONER GILINSKY: Is there a large relicensing problem here?

MR. MINOGUE: I think the perception of most of the people, certainly of the people who have commented to you from other sources, is probably not. We are a little reluctant to make that as a generic broadly based statement without an assessment because there may be some anomaly on one particular reactor type or it may be that the combination of reactor operations and experimental configurations might lead to a problem.

So I think there is a perception, first, that we need to identify where there is a commonality, group them and then do that on a generic basis and that would be the basis for whether or not to do a relicensing by rulemaking rather than by individual licensing procedures.

CHAIRMAN PALLADINO: So you wouldn't do that right away?

MR. MINOGUE: I think the study that I just described could not realistically be done on the time involved in going out with this rule for comment. So we did not see any reason why this could not be done concurrently with the comment period.

The regulation as it would be proposed for comment would make clear that this is the approach we are using and people could comment on that.

CHAIRMAN PALLADINO: Yes. I think we ought to say what we have in mind or what one of the possibilities might be so that we do get comment.

MR. MINOGUE: But this is not something that is just self-evident. With all due respect to the other parties who have presented to you in this matter, I doubt very much if they had any extensive studies to support their assertion. I think it is just a feeling that this is not likely to be a significant change. That is in the first paragraph.

Now in this draft staff requirements memo we identified two options. The first option "A" would be an option that would convert of the reactors, except where there is some unique purpose. That is wording of course from the previous Commission guidance. We would expect that there are very few such reactors, very few.

COMMISSIONER GILINSKY: Let's see, why do you put it that way rather than adding for which there is not lower enrichment fuel available? In other words, even if the purpose is unique, if you can achieve the same result with lower enriched fuel, why would you allow an exemption?

MR. MINOGUE: We used the term "unique purpose" because that was in the Commission guidance. The intent is that this would be a base where let's say in order to achieve a beam at precisely a certain level of intensity and precisely at a spectral distribution, if that could not be achieved with low enriched fuel, that would be considered a unique purpose.

CHAIRMAN PALLADINO: And that is the way we had it in our earlier one. We said "This is with regard to no new research at test reactors be licensed for use of HEU fuel unless the applicant shows that the unique purpose of the project cannot be achieved without using HEU fuel.

COMMISSIONER GILINSKY: Well, that seems to have been left out here as I read it.

MR. MINOGUE: Mr. Gilinsky, this memo would not replace the previous guidance. It supplements it. And that covered in the previous guidance.

COMMISSIONER GILINSKY: That is the sense of it?

MR. MINOGUE: That is the sense of it, and it is clear, although I wouldn't prejudge a matter that would be determined by the Director of Licensing. That is on the next page.I would expect there are very few such reactors. I think we are talking about two to be precise. This is not a large group.

COMMISSIONER GILINSKY: Well, in time there may in fact not be any if fuels are developed with allow you to produce ---

MR. MINOGUE: I am not sure that nobody would build another one with this problem given ---

COMMISSIONER GILINSKY: No, no. What I am saying is if fuel is developed which will allow these reactors to do precisely what they need to do, then they will no longer meet the condition for exemption.

MR. MINOGUE: If that were to happen, yes.

COMMISSIONER BERNTHAL: Just for my enlightenment, Bob, from some earlier testimony that we had, it sems to me that everyone understands that the flux or the intensity difference that you get between high enriched and low enriched is just minimal. You are talking 10 percent or something. And I have never understood why an experiment can possibly hinge on a 10 percent flux difference.

MR. MINOGUE: It is spectral distribution.

COMMISSIONER BERNTHAL: That was the rest of my question. I would assume that it is the spectral characteristics.

MR. MINOGUE: There are facilities, and there are more of these in a military context, but there are facilities that are designed very carefully. It is a very complex configuration of core, reflector region and exposure rooms or beam ports that are designed for precisely a given spectrum.

COMMISSIONER BERNTHAL: And it is because of the calibration work they have done that they would object to the conversion?

MR. MINOGUE: And the investment in all the hardware, because if you came in and changed the core around much, the input might change so much that the whole thing would have to be redesigned.

I worked on one such reactor many, many years ago and it is a very, very complex design problem. It is also a very unique application. It is not something that you would find in the university. The reactors we are talking about are not university reactors.

COMMISSIONER BERNTHAL: If you really want a certain spectral distribution that you have characterized very carefully, it is unlikely you would fix that by going to some other fuel no matter how cleverly designed. I mean that is always possible.

MR. MINOGUE: I wouldn't want to make it that strongly. I have a feeling that the design fuel that would fix it without involving a complete refabrication of the reactor would be very likely to be very costly. I wouldn't want to say I don't think it is possible.

CHAIRMAN PALLADINO: Bob, you said there are no university reactors in that category? Wouldn't MIT possibly fit?

MR. MINOGUE: No, and please, Mr. Chairman, let me emphasize, I am not prejudging something that this guidance said the Director of Licensing should determine. The MIT reactor would be in a group that in one of the previous Commission meetings you talked about looking to steps on an interim basis that would minimize the enrichment and go to a lower enrichment than high enriched, although not as low as 20 percent, and that is the group that we would assume the MIT and Missouri reactor would fall into, again not prejudging the question.

COMMISSIONER GILINSKY: Although again in time fuels may be developed to allow those to go to lower enrichment as well.

MR. MINOGUE: That is right. That is a much more clear-cut issue. Yes, much more clear cut.

CHAIRMAN PALLADINO: Jim, you had a comment?

COMMISSIONER ASSELSTINE: Yes, just one other, and maybe you are going to get to this, Bob, but under little "a," that paragraph, I take it the triggering point would as the HEU fuel is used up and as the replacement fuel is available is there another option?

CHAIRMAN PALLADINO: Whereabouts are you reading?

MR. MINOGUE: This is subparagraph "a".

COMMISSIONER ASSELSTINE: Okay. You may not be there yet.

MR. MINOGUE: That is correct. Going on in that paragraph, we would expect that in the licensing arena that it is to be determined by the Director of NRR that there would be an assessment of the economic factors and the factors of practicability. We have listed here some of the things that might be taken into account, scheduling of shipping casks, fabrication of replacement fuel, the question of financial support and reactor usage in terms of programs that are laid on.

So the presumption is that there would be a sort of as low as practicable determination that would be done case by case where a schedule would be worked out for an early replacement of fuel for all the reactors, but done in a way that took into account these factors that might be regarded as issues of practicability.

COMMISSIONER ASSELSTINE: Okay. But I gather that in essence you will balance that factors and it won't be an automatic well, we have so much HEU available for this particular reactor so we will just automatically wait until all that is used up rather than converting earlier if it is feasible to convert earlier.

MR. MINOGUE: No, I am sorry. The presumption of this is what we meant. We may not have worded it clearly. The presumption staff would have is that it should be done promptly. It is not a matter of waiting around, but it would act promptly.

COMMISSIONER ASSELSTINE: And in some cases that could well mean converting before you had used up whatever

HEU is available.

MR. MINOGUE: In most cases that would mean converting before you had used up the fuel.

CHAIRMAN PALLADINO: Where does it say that?

MR. MINOGUE: I am clarifying what we intended to say.

COMMISSIONER ASSELSTINE: This gives the opposite implication I think.

MR. MINOGUE: Option B is the less stringent option that we had also propose that we would staff out for you, and that would be an option where the life of facility fuel would be left as is. It would be a question of when you need to change, then you would change. So it is a less stringent option.

COMMISSIONER GILINSKY: The life of facility would mean the fuel in the core or fuel just sitting around or fuel which is yet to get there?

MR. MINOGUE: Well, it means in the context that we are talking here it is fuel in the core because when you look at the security that are in the next section there would be some attention given to the facility.

COMMISSIONER GILINSKY: Can I take you back to A for one moment. I would add after unique "unique and valuable."

CHAIRMAN PALLADINO: No. 1 which?

COMMISSIONER GILINSKY: After A, in paragraph A.

COMMISSIONER BERNTHAL: Are we going to decide which research is valuable?

COMMISSIONER GILINSKY: Well, there has to be some sort of decision of that sort.

MR. MINOGUE: Well, is a reactor that makes the large percentage of the medical isotopes used in medical pratice in this country and the other is a government reactor used for specialized research requiring unusual spectrum.

COMMISSIONER BERNTHAL: One of them is primarily used for isotope production, but then for them the flux is really all that matters, isn't it?

MR. MINOGUE: That is right. The example I was giving before was the NBS reactor. That is not a question of spectrum, that is right. It is just the flux.

CHAIRMAN PALLADINO: I would hate to put "and valuable." I am not sure I know how to assess it.

COMMISSIONER GILINSKY: Well, it can't be any all unique purpose.

CHAIRMAN PALLADINO: We will examine the purpose.

COMMISSIONER GILINSKY: I hope so.

CHAIRMAN PALLADINO: I am sure we would.

(Laughter.)

COMMISSIONER GILINSKY: Why does "valuable" trouble you?

CHAIRMAN PALLADINO: It applies an assessment that I think is going to get us into a lot of ---

COMMISSIONER GILINSKY: But you are going to have to make that sort of assessment one way or another.

COMMISSIONER BERNTHAL: I think that is a difficult area and in the end the Commission would put itself in the position of judging the value of the research being done on a given reactor, and I am just not sure ---

COMMISSIONER GILINSKY: That is right. You have to weigh that against some kind of a risk. You do that all the time every time you license a power reactor. It may be a little easier to put a dollar value on power, but you did it when you approved the Clinch River reactor based on a notion that that information was valuable. That is why they got an exemption.

COMMISSIONER BERNTHAL: What was the name of that again?

(Laughter.)

CHAIRMAN PALLADINO: Well, I would be satisfied with unique purpose. I think that could cover what we need to under that.

MR. ONG: Commissioner Gilinsky. Maybe I could help with an old staff paper. It is four years old in this area. You could paraphrase something like these power reactors contribute to the U. S. ability to provide needed nuclear training and research in the production of radioactive isotopes in medical applications. That is how they put the value on the regulatory analysis.

CHAIRMAN PALLADINO: I would like to see some simple, straightforward statements of the situation. I think the way it was worded the first time in the staff requirements memo of June seems like a straightforward assessment of what we have to deal with.

COMMISSIONER GILINSKY: Well, this is helpful because it does have that additional phrase at the end.

CHAIRMAN PALLADINO: My feeling would be after we are through we put together a composite SRM.

MR. MINOGUE: Our intent was to use the same thought you had previously. The point I was really trying to stress was that there are very few reactors that would fall into that category. That was the point I was really trying to raise.

COMMISSIONER ASSELSTINE: There are essentially two.

MR. MINOGUE: Without prejudging the matter, it looks like there are just two and that is not a lot.

COMMISSIONER GILINSKY: But again I think the Chairman has a good point and it is useful to add on the

the unique purpose of the project cannot be achieved without using a HEU fuel.

CHAIRMAN PALLADINO: Yes, I think that is important.

MR. MINOGUE: The other part of this memorandum deals with the question of a series of candidates for interim security measures that might be taken ---

CHAIRMAN PALLADINO: Well, let's see, did we cover all the aspects of sub "a" under A?

MR. MINOGUE: Yes, sir we covered them all.

CHAIRMAN PALLADINO: Well let's see, and I am reading in the middle of the paragraph, "If a suitable replacement fuel is not expected to be available within the overall schedule of the DOE reader program, rules shall provide for replacement of HEU with fuel of enrichment as close to 20 percent as practicable."

MR. MINOGUE: Yes, we covered that. That was one of the points that the Commission discussed at the meeting in December.

CHAIRMAN PALLADINO: See, my problem is that 20 percent seems to be a dividing line and to get down to as close as practicable to 20 percent, I think they ought to be encouraged to get down to below that 20 percent. Of course, there may be some other percentages in between that I am not aware of.

COMMISSIONER GILINSKY: Well, I think you must have had in mind the MIT and Missouri reactors which you thought couldn't get down there right away, but ought to be encouraged to get down as far as they can because it does make a difference if they are down at 30 or 40 percent instead of 90 percent.

MR. MINOGUE: Right.

COMMISSIONER GILINSKY: That makes a lot of difference.

CHAIRMAN PALLADINO: well, what about sub "b" under A?

MR. MINOGUE: Sub "b" would be similar, but would apply only to new fuel that had to be acquired during the term of the license. So it is a less stringent action in sub "a".

COMMISSIONER ASSELSTINE: why do we want to include that one? Why not just go with the proposed rule that eccompasses "a"?

MR. MINOGUE: I think that is your choice. We tried to draft something here that you could use as a talking point. The sense of the several Commission meetings on this was that it did not appear that we ought to exclude that option and we ought to give you a chance to say Yea or Nay on it.

CHAIRMAN PALLADINO: Now in trying to decide on

Yea or Nay on this, we are trying to assess the problem that might have to do with security of having it at the particular location versus the problem of transporting it back. I guess that is not an easy one to do. This one we ought to talk about a little bit.

MR. MINOGUE: In the second part of this memo there are a number of candidate security measures identified that could be done either in a companion rulemaking, in a separate rulemaking or by some licensing action or some mix thereof. Some of them are relatively straightforward and some are much more complex.

COMMISSIONER GILINSKY: Let me ask you, what would be the effect of paragraph B? How many reactors would be caught up in that and how many would be relatively unaffected.

MR. MINOGUE: I believe it is 18 that would not be affected in terms of their core loading.

CHAIRMAN PALLADINO: Eighteen out of how many?

MR. MINOGUE: Eighteen out of roughly 25 I think. It is the university reactors that I am talking about. That is not the whole family.

COMMISSIONER ASSELSTINE: So for all practical purposes then, most reactors would not be converted then under option B.

MR. MINOGUE: That is correct. Under option B most of the university reactors would not be converted.

CHAIRMAN PALLADINO: Any other thoughts on paragraph B?

COMMISSIONER GILINSKY: I guess I wouldn't hang on to it if it isn't doing anything.

(Laughter.)

COMMISSIONER ASSELSTINE: I think I would just put out A.

CHAIRMAN PALLADINO: I am just trying to see what your thinking is.

MR. MINOGUE: All you need to do is just draw a red line through it.

(Laughter.)

COMMISSIONER ASSELSTINE: B basically says you don't do very much.

CHAIRMAN PALLADINO: That is right.

COMMISSIONER BERNTHAL: Yes. If we are going to do B we are spending a lot of time, it seems to me, over nothing.

CHAIRMAN PALLADINO: Is it the concensus that we focus on A and not on B?

COMMISSIONER ASSELSTINE: I would focus on A.

COMMISSIONER ROBERTS: (Nodding affirmatively).

COMMISSIONER BERNTHAL: Yes, I agree with that.

CHAIRMAN PALLADINO: And I gather you do,

Victor?

COMMISSIONER GILINSKY: Yes.

CHAIRMAN PALLADINO: All right.

Are you through?

MR. MINOGUE: Yes, sir, I am finished. I think the security measures, that the text speaks for itself.

CHAIRMAN PALLADINO: Well, let me make a suggestion. I was going to propose that we prepare an SRM addressing both the reduction to LEU and the interim security measures needed.

COMMISSIONER ASSELSTINE: Yes.

Let me talk about the security measures first. I would like to see an advance notice of rulemaking prepared as soon as reasonably possible to cover the security measures needed in the interim domestic research reactors and publish it for comment. I don't know how long it would take to develop such a rule and we might ask the staff what it would take to develop such a rule.

MR. MINOGUE: An advance notice you mean?

CHAIRMAN PALLADINO: An advance notice of rulemaking on the interim security measures at domestic research reactors.

MR. MINOGUE: I am reluctant to speak for Mr. Burnett, but I would assume given the amount of staff work he has already put into this, an advance notice, which in effect is a call for comments and information could be done very quickly.

MR. ONG: We understand from the staff that it would take about three months.

CHAIRMAN PALLADINO: Three months?

MR. MINOGUE: Not an advance, no.

CHAIRMAN PALLADINO: Not an advance.

Bob Burnett was going to rise?

COMMISSIONER ASSELSTINE: Well, the other question is do you want to do an advance notice or do you just want to do a proposed rule?

COMMISSIONER GILINSKY: I would rather take a little more time and ---

MR. DAVIS: An ANPR would give us more time of course as you well know.

CHAIRMAN PALLADINO: What will give you more time?

MR. DAVIS: An ANPR. The ANPR also would shift a lot of the leg work from us having to go out and find out information to have the licensee supply information to us in response to the request for comments.

I think the success of the ANPR would be on our ability to sensitize the non-power reactor community to take it seriously and really give us some pertinent comments on the questions associated with it.

COMMISSIONER GILINSKY: But you could get comments from a proposed rule. You know, these items aren't that complicated. For example, reducing holdings of fresh HEU fuel is just not that complicated a question.

MR. DAVIS: I agree that conceptually it sounds extremely simple, but then I think the universities particularly want to know well, who is going to pay for transporting it to wherever we are going to transport it to reduce it.

COMMISSIONER GILINSKY: Well, that is the purpose of a proposed rule. We are going to hear from them about all that.

MR. DAVIS: That is exactly right.

COMMISSIONER GILINSKY: But why through three iterations instead of two?

MR. DAVIS: Well, what I would suggest is rather than say they all are treated as a group, that you might want to give the staff a week or a couple of weeks to sit down and look at these five and others that might occur and come back to you and say this is the way we have chosen to handle them in the most expeditious way. Perhaps some of them should be ANPRed and some of them should be PRed and at the same time we can give you some feel for resources.

One thing I would like to point out to you in here is if we move into this mode with my current resources, I will have to suspend the Cat 1 rule. I just don't have the resources if what I am saying.

COMMISSIONER GILINSKY: What is Cat 1?

MR. DAVIS: The Category 1 non-power amendments on which the comments just closed.

CHAIRMAN PALLADINO: Okay.

COMMISSIONER ASSELSTINE: I wanted to ask you about that, the interaction between the two elements. I mean is it something that logically makes sense to hold up on the Category 1 proposed changes until this ---

MR. DAVIS: Well, it would be best to do them in parallel, but these you see here, the interim security measures here are Category 2 interim measures. We now have interim Category 1's which have been implemented.

CHAIRMAN PALLADINO: And you are satisfied with the interim Category 1's?

MR. DAVIS: Well, we propose to go to final, although we have not come to that point, but I think we can live with the Category 1 for the period of time that it takes us to get these Cat 2's in place.

COMMISSIONER ASSELSTINE: And they are effective on an interim basis?

MR. DAVIS: We have some interim requirements which are effective for the Cat 1 facilities.

COMMISSIONER ASSELSTINE: Okay.

CHAIRMAN PALLADINO: Let me tell you why I thought of the advance notice of rulemaking as being a reasonable way to approach it.

It was my impression from idle conversations I had or a side conversation that an advance notice of rulemaking could be done in a couple of weeks and that then while the comments are coming in they can continue to study some of these features in more detail and be prepared to cope better with comments that you might get.I am not opposed to the other way around, but ---

COMMISSIONER GILINSKY: I must say I would urge that we, if necessary, take another week and come out with a proposed rule.

CHAIRMAN PALLADINO: Well, see, I gather it is going to take several months to come out with a proposed rule.

COMMISSIONER GILINSKY: I just can't understand why. I really can't.

MR. DAVIS: Well, what I would like to do is sit down and really examine it and lay out what it would take. One thing you have to recognize, and I don't like to keep talking about resources, but my Safeguards Division has gone down 20 percent over the last five years. It has been, as I think we have told you, based on these budgets. It is what we call a bare bones budget based on a stabilized program.

Now right now this is the beginning of instability which means that we have got to go back and look at what am I going to quit doing to do this which I didn't have planned for three months ago.

COMMISSIONER GILINSKY: Well, look, you were talking about the Category 1 rules and that applies essentially to one reactor.

MR. DAVIS: Well, what we are saying is we would stop that right now and divert ---

COMMISSIONER GILINSKY: Well, the Category 2 applies to quite a larger number and it is the greater concern.

MR. DAVIS: That is right.

COMMISSIONER GILINSKY: And I think it would make a lot of sense to address this problem ---

MR. DAVIS: First, and that is what we are suggesting.

COMMISSIONER GILINSKY: And that would be the way to handle the resource problem.

MR. DAVIS: What I would like to do is get a tighter fix on time. Rather than you presume I will do it in two weeks or presume I will do it in three months, if we can get a tighter fix on time on what we can deliver in those time periods.

CHAIRMAN PALLADINO: So our staff requirements memo would ask you to make a proposal on how we approach this?

MR. DAVIS: Well, it should inform the Commission of a schedule and approach to these matters so we can do it by some date certain.

COMMISSIONER ASSELSTINE: I would be willing to give John a week or two to look at options which would include I gather looking at how fast you could proceed on each one of these items and maybe moving some of them fairly quickly.

MR. DAVIS: Surely, and if it appears that the ANPR is easy to do, we would start writing it, but I think we need to sit back and ---

COMMISSIONER ASSELSTINE: Or a proposed rule.

MR. DAVIS: Or a proposed rule.

COMMISSIONER GILINSKY: Well, the ANPR is kind of deceptively simply because you don't have to do a whole lot of work.

MR. DAVIS: Of frontend work.

COMMISSIONER GILINSKY: Right. So you don't have to think it through quite to the same extent that you would in a proposed rule, but it also doesn't get you very far.

MR. DAVIS: It gets you to where you should be with a lot more information. It gets you a lot of information front-end which is really not in the form that you would like to have it if you were writing the proposed rule. It is a way to test the waters is all.

COMMISSIONER GILINSKY: Well, I will tell you, if this were ATWS and we were talking about millions and millions of dollars for each reactor and a hundred reactors and so on and it is a complete new approach, then the ANPR may make sense, but for an item of this size and the relatively speaking lack of complexity, I must say I would go with the proposed rule.

CHAIRMAN PALLADINO: I wouldn't mind going with a proposed rule, but not necessarily for the comments you made, because the monies to a university are quite significant.

COMMISSIONER GILINSKY: Well, I mean that is why you have proposed rules.

CHAIRMAN PALLADINO: To the follow that only has $10, $5 is a big hunk of money.

COMMISSIONER GILINSKY: Sure, but that is why we have proposed rules. This is their opportunity to comment and we hope we will give them enough time and they will comment fully and it will be taken into account.

MR. DIRCKS: I think what he is trying to say is that in order to go with a proposed rule you are going to need some information in here on what you are going to require.

COMMISSIONER ASSELSTINE: That is right. That is the purpose of giving John a couple of weeks to take a look at what it would take to do that and when he could do it.

COMMISSIONER GILINSKY: That is right.

CHAIRMAN PALLADINO: So our staff requirements memo would ask you to develop an approach and a time table for achieving the interim security measures.

MR. MINOGUE: Can I raise a question, Mr. Chairman?

CHAIRMAN PALLADINO: Sure.

MR. MINOGUE: It is not clear to me that we couldn't separate the two actions. "A" could be done as a separate action.

CHAIRMAN PALLADINO: Yes, and I think there would be value in doing that.

COMMISSIONER ASSELSTINE: Yes.

CHAIRMAN PALLADINO: All right. Then the other one I would propose that they develop an SRM that asks for an integration of the item A and the June memo. My suggestion would be to ask OPE to write up both these SRM's.

COMMISSIONER GILINSKY: Let's see, when you say integration, would it be items that aren't covered in this ---

CHAIRMAN PALLADINO: That is what I was trying to find out. What is it that is in there that isn't covered in there?

MR. MINOGUE: Well, it was our intent to cover everything.

MR. DIRCKS: We might have missed it, but we thought everything that was in June was contained in the February 3rd ---

CHAIRMAN PALLADINO: Well, I am not clear what it is then that we have got to do under "A" sub "a" that isn't covered in here and it is actually more detailed.

MR. MINOGUE: It was our intent to provide additional detail on some of the points but not to paraphrase all of it in the June 21st guidance.

CHAIRMAN PALLADINO: I still think it would be appropriate to take whatever pertinent sentences are in here, combine it with that and get one clear SRM on this subject.

COMMISSIONER ASSELSTINE: Yes.

CHAIRMAN PALLADINO: And my proposal would be to ask OPE to do it.

COMMISSIONER GILINSKY: I must say I would go with the addition of that extra phrase from No. 1 in your paper, but I suppose if you feel -- well, let's see, these are just additional comments. So we are just talking about the front page here.

CHAIRMAN PALLADINO: I think so. I don't remember is there is something on the back page.

COMMISSIONER GILINSKY: I think it is just you comment and I comment, and I am castigating a lax approach.

(Laughter.)

CHAIRMAN PALLADINO: My comment was that I would like to hear more about it and I am glad we heard more about it.

COMMISSIONER GILINSKY: Yes.

CHAIRMAN PALLADINO: I am more convinced than I had been.

COMMISSIONER GILINSKY: Well, I am glad, too.

(Laughter.)

COMMISSIONER GILINSKY: Well, why can't we deal with it right here. I mean there are three points and we could just read them off and just see whether they are covered or not.

CHAIRMAN PALLADINO: We can either do that or we could give it to OPE and ask them to come back with something in the next couple of days.

COMMISSIONER GILINSKY: Well, are they going to come back in a couple of days?

MR. RATHBUN: That is what we plan to do.

COMMISSIONER GILINSKY: Okay.

CHAIRMAN PALLADINO: Rather than try to write it here because we will rewrite it anyhow.

(Laughter.)

COMMISSIONER GILINSKY: Wait a minute. Down here you have "Both 1 and 2 are based on Congress funding DOE to provide the appreciably lower enrichment LEU fuel for university reactors." That meant what?

CHAIRMAN PALLADINO: That meant whatever was written ---

COMMISSIONER GILINSKY: You mean this whole thing is null and void unless ---

CHAIRMAN PALLADINO: That is the way it reads.

MR. MINOGUE: Financial support is one of the things that is explicitly identified that would be considered by the Director of NRR in arriving at the schedule.

COMMISSIONER GILINSKY: Well, it is one thing to say that when a low enrichment fuel is availalble is has to be used. If we are tying it to some sort of Congressional appropriation, then that is different. I mean how would you interpret your point 3 here?

CHAIRMAN PALLADINO: I didn't write that point 3. That was written by the people that were the majority last time.

COMMISSIONER GILINSKY: Maybe I wrote it.

(Laughter.)

CHAIRMAN PALLADINO: I think you did.

(Laughter.)

COMMISSIONER GILINSKY: Okay. Well, if we can have it in a couple of days, let's do that.

CHAIRMAN PALLADINO: Okay, and there is this point of consideration being given to including in the rule some provision for extending licenses.

COMMISSIONER GILINSKY: You are talking about rulemaking or something like that?

CHAIRMAN PALLADINO: Yes, in the eventual rule.

MR. MINOGUE: We are trying to facilitate that process.

COMMISSIONER GILINSKY: That is perfectly reasonable.

CHAIRMAN PALLADINO: Okay. Well, all right. What is today? Monday. Two days is Wednesday. At the close of business Wednesday. Okay.

Well, I was hoping we would be able to do this in less than an hour, and unless you have other points that you think we need to cover, I think we have done it.

All right. Well, thank you very much.

We will stand adjourned.

(Whereupon, at 3:50 p.m., the meeting adjourned.)

ORIGINAL

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of: Discussion/Possible Vote on Proposed Rule on LEU/HEU Fuel.

COMMISSION MEETING

OPEN MEETING

Location: WASHINGTON D.C.

Date: MAY 31,1984

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION
POSSIBLE VOTE
DISCUSSION/ON PROPOSED RULE ON LEU/HEU FUEL
PUBLIC MEETING

Nuclear Regulatory Commission
1717 H Street, N.W.
Washington D.C.

Tuesday, May 31, 1984

The Commission met, pursuant to notice, at 2:00 p.m.

COMMISSIONERS PRESENT:
NUNZIO PALLADINO, Chairman of the Commission
JAMES ASSELSTINE, Commissioner
FREDERICK BERNTHAL, Commissoner
THOMAS ROBERTS, Commissioner
VICTOR GILINSKY, Commissioner

STAFF AND PRESENTERS AT COMMISSION TABLE:
S. CHILK
W. LAHS
R. BERNARO
J. ZERBE
S. TRUBATCH

AUDIENCE SPEAKERS

R. MINOGUE
R. BURNETTE

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Chairman Palladino: Good afternoon, ladies and gentlemen. This meeting is for the purpose of discussing a proposed rule that would require the reduction of the use of high enriched uranium in test and research reactors.

The rule has been presented at the direction of the commission based upon previous discussions with the staff.

The meeting has been advertising as including a possible vote on the rule. However, I do not know if the commissioners are prepared to vote on this issue today, since the time available for detailed review of the paper has been brief.

I for one am considering a couple of areas in which I may want to see changes in the proposed federal register notice.

Here I should also note that we will not have ACRS comments on the paper until mid-June, and thus my vote and possibly the vote of other commissioners might be subject to further considerations upon receipt of the ACRS comments.

I should also note that the paper is identified as an occasion vote and can be voted upon after the meeting if the commission so desires. Are there any additional opening remarks?

Commissioner Gilinsky: I thought we were going to deal with it here and wait to see if the ACRS, assuming they're done with the paper before us, whether the ACRS had any violent objections.

Chairman Palladino: Well, we can vote on it if the commission is ready to vote. I am considering some proposed changes that would make it more acceptable to me, but I haven't worked those out yet.

Commissioner Gilinsky: You'll tell us about them.

Chairman Palladino: I can tell you generally about them, but if I had the specifics, I'd be able to make suggestions on some changes.

Commissioner Gilinsky: Well, let's hear about the subject.

Chairman Palladino: Well, the subject has to do--there are several subjects, one of which I'm going to explore this afternoon.

One has to do with whether or not the summaries should say anything about DOE funding, in the first paragraph. I haven't decided what, if anything, it should say.

And then there's the question of the reason for doing this, I don't think is quite well enough spelled out. The way that's spelled out--this is background information--the way it is spelled out may have to do with whether or not I can include any comments on DOE funding.

The third rule that I'd like to explore this afternoon is the same question that I asked this morning, and that has to do with relative risk of keeping those cores that have lifetime fuel, whether you have risk with that, versus the risk of having the concentrated shipments of fuel back to wherever it goes in some distinct period of time, which, in a sense, constitutes a passable target of opportunity for which there is good condition for plan.

I'd like to hear the staff comments on that issue as well. So those are the areas in which --

Commissioner Gilinsky: Does the rule now mention DOE funding?

Chairman Palladino: It talks about that.

Commissioner Gilinsky: It certainly does, yes.

Chairman Palladino: I may turn out--I don't want to say something that I'll regret, but I did make one suggestion to my staff, and my staff showed me some holes in it, and that's all I've done.

Commissioner Gilinsky: Did you think it

shouldn't refer to the DOE funding?

Chairman Palladino: It depends on--see, the problem is, if we are doing this because there is some real question on national security, then cost shouldn't be in there.

If, however, we have achieved an adequate level and this is an incremental mean, then maybe costs can be considered.

That's where I am having my difficulty in my thinking.

Commissioner Gilinsky: I think there's a danger in trying to be too logical.

Chairman Palladino: Well, all I can say is, I am not ready this afternoon to say I may, although I may have some observation to make about my inclination at the end of the meeting.

Commissioner Gilinsky: Also on that point, I would be inclined to leave out the matter of DOE funding, understanding that as a practical matter it's going to influence things very heavily.

As we explicitly make this contingent on DOE funding, that is the probability of getting DOE funding.

Chairman Palladino: I agree. And that's one of the holes that was pointed out to me by my staff. So all I'm saying is, there are several areas where--and they're all in the background--background or apart, and I do have that one question that would relate to my feeling about lifetime cores. I'd like additional information.

Commissioner Gilinsky: I guess we heard about that from the staff this morning.

Chairman Palladino: I'd be interested in any comments this afternoon they have. Okay? Any other opening comments, questions? All right. Then we'll turn the meeting over to Mr. Bob Benaro.

Mr. Benaro: Thank you, Mr. Chairman. As you said, we're here to discuss the proposed rule for limiting the use of high enriched uranium in research and test reactors.

Here at the table with me is William Lahs, the senior staff member, who prepared the rule and is principally responsible for it.

In the audience, Bob Minogue, the director of research, and Dr. Kelber from the Office of Research, are here, and Bob Burnette from NMSS, who spoke to you this morning on the security aspects of this problem in the 10:00 o'clock briefing.

The first slide here just shows you the context or the chronology which brought us here today.

5/31/84

LIMITING THE USE OF HEU IN RESEARCH AND TEST REACTORS

BACKGROUND INFORMATION

- POLICY STATEMENT (AUGUST 1982) EXPRESSES INTEREST IN REDUCING USE OF HEU IN DOMESTIC AND FOREIGN RESEARCH REACTORS
- OPE REPORT ISSUED ON OPTIONS FOR IMPLEMENTING POLICY. (MARCH 1983)
- STAFF PLANS FOR PROPOSED RULE OUTLINED IN SECY 83-349 (AUGUST 1983)
- COMMISSION MEETINGS HELD ON IMPLICATIONS OF CONVERSIONS (DECEMBER 1983, JANUARY 1984, FEBRUARY 1984)
- STAFF REQUIREMENTS MEMO ISSUED ON CONTENT OF PROPOSED RULE (FEBRUARY 23, 1984)

In August of 1982, we published a policy statement which supported the DOE program for reducing enriched uranium content in research and test reactors.

OPE gave you a policy paper in March of '83, which covered options which included no new use of high enriched uranium in research and test reactors, as well as conversion of existing reactors, possibly even if they don't need further refueling in their life--the so-called lifetime cores.

There were discussions through the winter, that you had with staff, several meetings, and then the staff requirements memo came off February 23 of this year, and you directed us to prepare this rule which is before you now, some three months later.

I'd like to point out on slide number two some very important relationships. We frequently speak of this activity as if it is sometimes unilateral, or, at most, bilateral.

It's really a rather intricate interaction between the DOE program licensee activities, some 30 or 31 licensees, depending on how you count them, and the NRC.

At the top of this chart, I have listed the general time line, the projected time line for the DOE program to develop and demonstrate fuels and, very

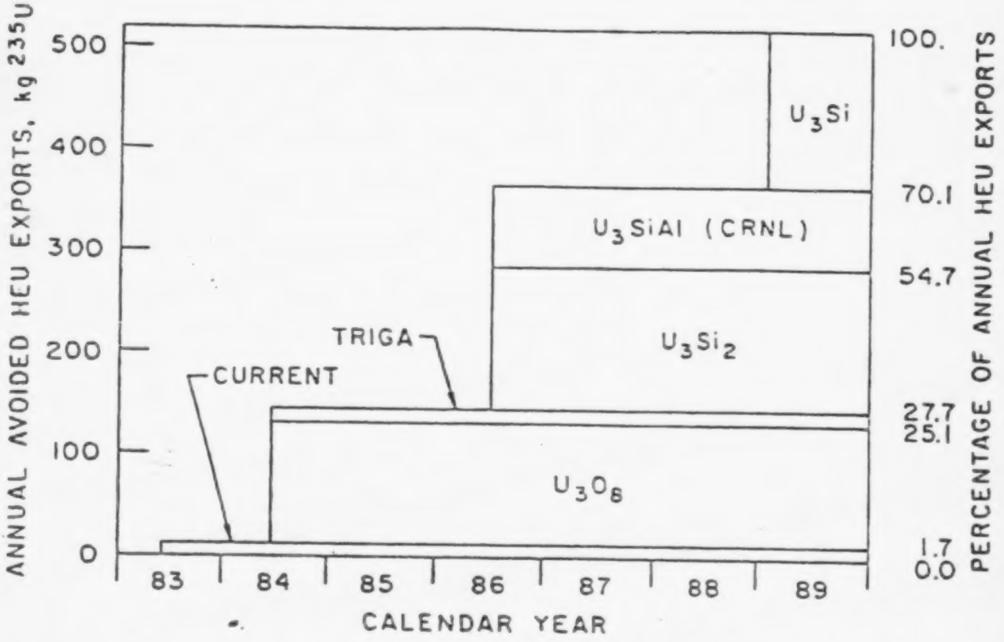

Fig. 3. Potential Avoided U.S. HEU Exports for Research and Test Reactor Fuels.

important, to gather data from those demonstration tests, which provide the basis for safety analysis.

Now, that time line, running from what has been done already, 1984, on to the end of this decade, picks up the aluminide fuels in the early time frame and goes to the higher density, more advanced silicide fuels later.

Now, depending on the nature of the reactor design, basically the fuel and the configuration is going to give you the spectral mix you get in the reactor.

The conversion to low enriched uranium with minimum impact may require a low density fuel or may require a higher density fuel.

The licensees who would be affected would look to this program for the appropriate fuel type that would suit their facility, their conversion, and presumably would select from that set the basis on which they would come to us, the NRC, and say, "We intend to convert according to this schedule, to this type of fuel."

Or they would select the other alternative we'll talk about, as pleading unique purpose. The important thing to see is, they have to get the fuel from DOE, but from the DOE program, the safety analyses they wll rely on must be generated and the data in place so that, in effect, we have generic or class-specific safety analyses.

And over to the left-hand side of the chart, you'll see a dashed line with an arrow pointing to up, toward the DOE program, and over toward NRC licensing.

This is a dialogue that has just begun where we're talking to DOE to ensure that the appropriate data, the appropriate analyses and other information needed is already generated in the DOE program when the licensee gets to use it.

It's a very important point. Otherwise, the licensees would all be in the position of doing unique safety analysis and possibly even unique research.

So that the time line of this whole process, then, runs out for a number of years. In the simpler cases, conversion, which can be accommodated with one of the simpler improved fuels, the conversion could take place in the near time frame.

For something that is higher performance or higher requirements on the reactor, it could extend out quite a few years, all presuming that the DOE program is sustained.

And I think it appropriate to point out here there is an information paper from International

Programs, indicating the DOE programs in this area are having some funding pressure as well as we are.

I have further information that further pressure is there even beyond what was recently sent to you in that IP paper.

Chairman Palladino: Is this the program, the REDR program?

Mr. Benaro: Yes, the Reduced Enrichment Program. There are actually two programs at DOE but we generally refer to just the one.

Chairman Palladino: Let me ask you about that, the last type you just mentioned. There was a letter attached to that information paper. I think it was the DOE letter to state that mentioned the possibility of using funds from other agency, ACTA, and I think we were mentioned in particular.

Have we looked at all at the possibility of using our funds to help further that program along?

MR. BENARO: To my knowledge, no. I haven't--I don't know if someone from IP is here.

SPEAKER: Yes, we are.

Commissioner Asselstine: So ELD hasn't looked at the question of whether we can use our money to help fund those programs.

SPEAKER: That's right.

Chairman Palladino: May I ask when you are talking about funds, you mean helping with funds?

Commissioner Asselstine: Well, that's right. Or parts of it. For example, I gather the one element that seems to be in serious jeopardy of being delayed is developing the demonstration core.

You could slip the program about three years, and I gather the concern was an absence of $700,000 would have that consequence. So that's why I was raising the question.

Chairman Palladino: That's a question we probably ought to ask ELD.

Commissioner Asselstine: Yes, I think that's probably right.

Commissioner Bernthal: NRC directly providing the funds for that?

Commissioner Asselstine: Well, that's what DOE seemed to indicate in their letter, that they're not going to have the money but maybe we could come up with the money, or ACTA or somebody else could come up with the money to keep the program on track.

Commissioner Bernthal: Gee, I'd be very interested in exploring that. I think it opens a whole new range of possibilities for this agency.

MR. BENARO: Something that should be pointed out, this program is funded--this is the DOE program--is funded probably $4 million or $5 million a year, and some is something on the order or $30 million.

So the $700,000 could be the tip of an iceberg.

Commissioner Gilinsky: Still, it sounds like an awfully good investment.

Commissioner Bernthal: Sounds good to me.

Mr. Benaro: May I go on to slide three?

Commissioner Gilinsky: Let's you get into a whole new world.

Mr. Benaro: The basis and summary of this proposal is familiar to you because, in effect, you have directed it.

The rule we have here was in response to the staff requirements memo of February. Basically, no new licenses for non-power reactors will be issued for high enriched uranium fuel, and existing licensees will be required to convert to low enriched uranium or at least to high enriched uranium of as low as possible a degree of enrichment in accordance with an NRC determined schedule.

Chairman Palladino: There was another feature in the book about the availability of DOE funds.

PROPOSED RULE

BASIS AND SUMMARY

- PROPOSED RULE RESPONDS TO SRM OF FEBRUARY 23, 1984, PROVIDES, WITH CERTAIN EXCEPTIONS, FOR
    - NO NEW LICENSES FOR NPRs USING HEU FUEL
    - EXISTING LICENSEES, CONVERT TO LEU OR HEU OF REDUCED ENRICHMENT IN ACCORDANCE WITH NRC DETERMINED SCHEDULE
- EXCEPTIONS FOR "UNIQUE PURPOSE" CAN INCLUDE:
    - (I) A SPECIFIC EXPERIMENT OF PROGRAM REQUIRING HEU
    - (II) REACTOR PHYSICS OR REACTOR DEVELOPMENT BASED ON HEU
    - (III) RESEARCH PROJECTS BASED ON η FLUX LEVELS OR SPECTRA ONLY ATTAINABLE WITH HEU
    - (IV) REACTOR CORE OF SPECIAL DESIGN THAT COULD NOT PERFORM FUNCTION WITHOUT HEU

Mr. Benaro: Yes. Actually, well, that is absorbed in the NRC determined schedule, as I'll point out later. The availability of the fuel and the shipping casks and other resources are considered.

The unique purpose thing which was included in general terms, basically what we have here is four conceptual statements of uniqueness, whether it be neutron flux levels or spectron, the reactor physics of the experiment, special design of the core, it's the practicability of meeting the mission of this research or test reactor given that one would convert, and the move permits that, of course, by its very nature.

This would be the more onerous path because it gives to the licensee a much greater burden of demonstration of need and the necessary elements.

But there, too, we would carry the requirement that the enrichment be as low as reasonable, not necessarily just what it was to start with.

I have the next slide. Just for your information, we included a slide with a listing of the reactors.

The largest one on the list, I might point out, is the fourth one down on the left column, G.E. test reactor at Palacios, the 50-megawatt. It's been down for some time, shut down. It's still technically

NON-POWER REACTORS LICENSED FOR USE OF HEU FUEL

REACTOR	PWR (MW)	REACTOR	PWR (MW)
NBS	10	Mo. Rolla	0.2
		Ohio State	0.01
GA	1.5	Kansas	0.01
GEP-NTR	0.1	WPI	0.01
GETR	50	Purdue	0.001
Union Carbide	5	RPI	0.0001
Westinghouse	.01	Va-Cav.	0.0001
		Manhattan	10^{-7}
U. of Mo.- Col.	10		
MIT	5	UCLA	0.1
Ga. Tech	5	Fla.	0.1
		U. of Wash.	0.1
Rh. Is.	2	VPI	0.1
Mich.	2	Iowa St.	0.01
Uvar	2		
Lowell	1	U. Cal. S. B.	10^{-5}
Oreg St. U.	1		
Texas A&M	1		
Wisconsin	1		
Wash. St.	1		

a licensee, though. But the vast majority of these reactors are much smaller reactors. They are not the very large types.

May I have slide number five, please? Now, to implement this rule, as it is structured, it puts this burden on the director of NRR, in which the director of NRR will receive one of two things from the licensee.

The licensee will either give a proposal and schedule for conversion, or the alternative, at the bottom of the page, the request for unique purpose determination, in other words, the exemption.

In order to cover the conversion schedule--and this was the point I was making that the NRC evaluation and finding will absorb the issues of availability, the factors which control the ability of the licensee to convert and the schedule of conversion includes those first items listed there--the availability of the right type of replacement fuel, the appropriate density.

This includes what I said earlier. The test demonstrations and test data, the safety data, the safety analysis upon which one can assert that it is acceptable replacement fuel for that kind of reactor or that kind of purpose.

The availability of shipping casks, of course, has to be considered, and now we get into this fuzzier

PROPOSED RULE IMPLEMENTATION

DIRECTOR, NRR RECEIVES:

A. CONVERSION PROPOSAL

- O CONVERSION SCHEDULE WHICH CONSIDERS:
  1. AVAILABILITY OF ACCEPTABLE REPLACEMENT FUEL
  2. AVAILABILITY OF SHIPPING CASKS
  3. FINANCIAL SUPPORT (CONVERSION TO BE FINANCED BY FEDERAL GOVERNMENT)
  4. REACTOR USAGE
- O DIRECTOR, NRR DETERMINES FINAL CONVERSION SCHEDULE WHICH DEPENDS ON AVAILABILITY OF LEU FUEL
  1. ADAPTABLE TO LICENSEE'S REACTOR WITH MINIMUM MODIFICATION
  2. MINIMUM ADVERSE IMPACTS ON LICENSEE'S PROGRAM

B. POSSIBLE REQUEST FOR UNIQUE PURPOSE DETERMINATION area, the financial support. It is understood here that there would be no license fees, especially for a university reactor, anyway, but if facility conversions are needed, if modifications to the facility are needed, the direct costs to the licensee are not very clear here.

The objective is that the costs would be minimized, that the fuel would be furnished by the Federal Government, through DOE.

But other costs could be uncertain, or are uncertain, I should say. And, of course, the director of NRR will be considering the reactor usage, what is the mission, do they need certain critical flux or whatever.

His finding will be the binding. This is the NRR finding, will be binding thing for the licensee program, to have minimum impact on it and to get it converted in a timely way.

Chairman Palladino: If I may make a comment, it's that federal support for fuel for conversion, being supplied by the Federal Government, this is part of my problem.

If the reason for doing this is an urgent one, then I don't think you could say that financial considerations enter in.

If it is a substitute for what we're doing now or an alternative way of doing it, or some increment above what we're doing now, then I guess financial support could be a consideration.

Mr. Benaro: Well, I think what you're saying, Mr. Chairman, is that if this were a clear and proximate threat to the public health and safety, where one would say, "Whatever the cost, either fix it or shut it down," remove the threat, that doesn't appear to be the case.

What we're saying here, it is prudent, considering the threat of the international regime, but not the threat here, if it is prudent to reduce this availability or accessibility of high enriched uranium, and the entire context of this rule-making is on the premise that it is a federally-supported endeavor, that as a matter of national policy, the Federal Government is sponsoring the DOE programs which develop, demonstrate, and provide such replacement fuel and obtain this reduction so that the federal support is an underpinning of the whole endeavor.

Commissioner Asselstine: Well, isn't there also the notion that in the whole reactor research program anyway, there has been a large historical federal financial role in providing the fuel for these facilities, recognizing that they're of national benefit to be obtained from these facilities.

I think it's a little bit different than if you're looking at this like in the commercial power reactor area, where it's a utility responsibility to build and operate the plant and to pay for it, whereas here you're talking about a program where historically the Federal Government has been fairly heavily involved in financing it anyway, and given that historical financial involvement, given the national benefits to the RERTR program, that there's a notion that continuing federal support is not only useful but an appropriate element in this area.

Chairman Palladino: You would have to give exception. I'm trying to see how it fits into the point.

Commissioner Gilinsky: Frankly, this just isn't a casual thing. There are important reasons for shifting these reactors to lower enrichment, and I think the commission should not put up with these reactors going on indefinitely at high enrichment.

I would take out the reference to this only being done in the event that --

Chairman Palladino: Well, it doesn't say that right now.

Commissioner Gilinsky: I would simply have it understood. I mean, we all understand in the real world that it makes a difference whether Congress is going to come up with the money or not.

It decreases the probability that the money will be forthcoming if you don't constrain, you know. The action can depend on whether the money is forthcoming.

Chairman Palladino: It doesn't say it that way.

Commissioner Gilinsky: It gives that impression, at any rate.

Chairman Palladino: Well, I still think we're looking at what the reasons are.

Commissioner Gilinsky: The reasons are basically to eliminate a problem, however pressing you think it is, whether it's today's problem or tomorrow's problem. It eliminates a concern that one simply needs not to have nagging at you indefinitely.

Mr. Benaro: Mr. Chairman, I'd like to point out in your staff requirements memo of February 23rd, you made two points.

One, that the rule-making should request comments on the question of how much the issue of economic feasibility should influence the conversion of facilities to LEU, and also added the notation, this rule-making is based upon Congress funding DOE to provide appreciably lower enrichment and LEU fuel for university reactors.

Commissioner Gilinsky: The rule doesn't really say that.

Mr. Benaro: No. The rule seeks such comment. The statement of considerations, of course, is where we do it. We do seek such comment.

Chairman Palladino: You want to allow him to proceed?

Mr. Benaro: Yes. May I have slide five, please? No, no. Six. Now, the back one, please. The dependencies--yes. I think it's important for the commission to be aware that we have talked about cross-quantification of the rule-making paper only to a partial degree.

I mentioned earlier the overall cost of the RERTR program. That's not fully reflected in the cost benefit or regulatory analysis.

And further, we're assuming that relatively minor or only minor facility modifications would be required.

The spectrum of fuel available for the RERTR program appears to offer a reasonable alternative for

CRITICAL ASSUMPTIONS AND IMPLEMENTATION DEPENDENCIES

O REGULATORY ANALYSIS REPRESENTS PARTIAL COST QUANTIFICATION ASSUMING ONLY MINOR FACILITY MODIFICATION REQUIREMENTS

O COMPLETE CONVERSION ACTIONS DEPENDENT ON CONTINUED RERTR PROGRAM SUCCESS OVER NEXT 5-6 YEARS FOLLOWED BY DEVELOPMENT OF COMMERCIALLY AVAILABLE FUEL

O CONVERSION OF UNIVERSITY REACTORS ASSUMES THAT FEDERAL GOVERNMENT PROVIDES BOTH REPLACEMENT FUEL AND SUPPORT FOR ADMINISTRATIVE LICENSING COSTS INCLUDING CONVERSION SAFETY ANALYSIS

O DETAILED CRITERIA FOR "UNIQUE PURPOSE" AND FINAL SCHEDULING DECISIONS AS WELL AS GENERIC LICENSING REQUIREMENTS DEVELOPED B NRC IN A REASONABLE TIME FRAME WITH COOPERATION OF DOE virtually every reactor, or almost every reactor.

Commissioner Gilinsky: What sort of costs are we talking about at the university end?

Mr. Benaro: I have those on a later slide, if you'd just bear with me. I'm just going to touch on them. I have them accumulated.

Now, the complete conversion actions, you notice the time line I just indicated here, roughly five to six years, the earlier parts of the program could take care of a fair population of the reactors.

I don't mean to suggest that all conversions would wait that long. They would be spread out over time.

The more unique a type of fuel, the higher performance fuel you need, the longer it would take it, because that's the way the program is set up.

As we've said, it is a very strong federal support, and the detailed criteria for the unique purpose in the final scheduling decision are such that it's not fully clarified yet, and they would develop further as the staff works out with this fuel development program.

May I have the regulatory analysis slide? We have certain assumptions. One of the assumptions here is that the technology does exist or is being put in

REGULATORY ANALYSIS

ASSUMPTIONS:

- TECHNOLOGY TO REPLACE HEU FUEL WITH LEU FUEL OR REDUCED ENRICHMENT HEU FUEL IS, OR WILL BE, AVAILABLE WITHIN THE NEXT SEVERAL YEARS (I.E., RERTR PROGRAM)
- TECHNOLOGY WILL ALLOW MOST TO CONVERT AND CONVERSIONS TO TAKE PLACE WITHOUT ANY SIGNAFICANT DECREASE IN SAFETY MARGINS OR MAJOR FACILITY MODIFICATIONS
- NO SIGNIFICANT ADVERSE IMPACTS CAUSED BY SHIPPING CASK AVAILABILITY, CONVERSION COSTS OR REACTOR PERFORMANCE
- REPLACEMENT OF HEU FUEL TAKES PLACE AS RAPIDLY AS ACCEPTABLE REPLACEMENT FUEL IS AVAILABLE

place to do these replacements. We don't foresee significant technical problems. Of course, we can't guarantee they won't occur.

But basically, if the program continues essentially as it's structured, we foresee a successful availability of technology to make conversions accepted.

Chairman Palladino: This is seven?

Mr. Benaro: Yes, this is slide seven.

Chairman Palladino: You skipped six?

Mr. Benaro: And then the degree of budget support, remember how the finding, the schedule for conversion depends on the availability of a lot of things.

These other two assumptions are just related to that. It is based on the premise of the federal funding.

Now, if I could skip to slide nine, please. We have the conversion costs. One of the costs of conversion is the one that was discussed somewhat this morning, and that's the one-time safeguards and radiological risk cost with the transportation from lifetime cores.

In essence, you have a reactor that was supposed to be defueled once, and now you have an

REGULATORY ANALYSIS

CONVERSION COSTS*

INTANGIBLE

- ONE TIME SAFEGUARDS AND RADIOLOGICAL RISK WITH TRANSPORTATION FROM "LIFETIME" CORES
- POTENTIAL LOSS IN CAPABILITIES FROM CURTAILMENT OR LOSS OF SPECIFIC REACTOR OPERATIONS OR FUNCTIONS

TANGIBLE

QUANTIFIABLE COSTS	MILLIONS
LOST FUEL FABRICATION	\$6.2
TRANSPORTATION	\$1 - \$2
MINOR FACILITY MODIFICATION	\$0.25
ADMINISTRATIVE AND LICENSING	\$1.5 - \$3

UNQUANTIFIED COSTS

CONVERSION FOR UNUSUAL REACTOR DESIGNS
LOST REVENUE FROM ANY ACCEPTED CAPABILITY LOSS
NRC LICENSING COSTS

*NO RERTR PROGRAM COSTS HAVE BEEN INCLUDED intermediate defueling for the convergent core, and as a result, that HEU that you're pulling out is pulled out of the core that one time, and you have the radiological risk.

The curtailment of facility use, you know, whatever limitations might come, is another intangible cost.

As I said before, most of the experts seem to be telling us that the essential purpose of the reactors won't be all that significantly affected, except for cases.

Now, the tangible costs we've broken down here of lost fuel fabrication--you might say unused fuel or spent, prematurely expended fuel, and transportation, and then some minor facility modifications.

The first cost is clearly a DOE type federal cost.

Chairman Palladino: Are these the total costs for all these?

Mr. Benaro: These are the total costs for the licensees.

Chairman Palladino: I'm sorry. For all of them?

Mr. Benaro: Yes, for all of them. And then the facility modifications, it's an assumption of very little, if anything, there.

Then administrative and licensing costs would be the principal licensing costs. We have here a general estimate of $1.5 to $3 million for the set, for all 31 licensees.

It's a very elastic number, it's an indefinite number. The assumption, once again, is that the greatest pains would be taken in the RERTR program by direct dialogue with DOE to make sure that the necessary safety data are available and in the right form, so that we can use generic safety analysis.

Of course, as I said before, there will be no fee, but still, it will have some cost. So this last cost of $1.5 to $3 million is what I would consider clearly the direct cost of the licensees.

Commissioner Asselstine: Does this include, then, the new fuel fabrication costs as well?

Mr. Benaro: No.

Commissioner Asselstine: That's in that underlying DOE program.

Mr. Benaro: Yes, may I have slide ten? So that brings us to where we are today.

Commissioner Gilinsky: One thing in this analysis is the cost of increased security, which the

PROPOSED RULE STATUS

- o TRANSMITTED TO ACRS ON APRIL 20
- o COURTESY COPIES TO OPE AND CAG. (EARLIER BUT SUBSTANTIALLY SIMILAR DRAFT)
- o READY FOR PUBLICATION PENDING OMB CLEARANCE

commission may or may not lay on in the future. Some suggestion that we made some steps in this direction this morning.

Mr. Lahs: That's in the regulatory analysis but not in the slide.

Commissioner Gilinsky: Okay. Good. The other is, you know, in the safety area. We talked about safety gains or accidents avoided and so on.

Should there be any material, even though I would say rather small quantities of material stolen anywhere, I think a terrific security regime would be laid on everyone, not to speak of the harm that would come from the material being stolen.

It's pretty hard to put a number on that. It's going to dwarf all the numbers here.

Mr. Benaro: Basically, if you look at these costs here, it's the RERTR program itself that is the cost.

These other costs do not loom all that large. You know, it's the federal cost here. But in this rule, as I was saying, was prepared by April 20 and sent to the ACRS for review, they have it and are scheduled for a subcommittee meeting on the 12th of June.

The rule, of course, is before you as well.

We sent copies to OPE and the cost analysis group. We are awaiting OMB clearance. We have gone out to them, also, so recognizing those limitations, the rule is ready for publication as you see fit.

Commissioner Asselstine: Can you refresh my memory on what the cost estimates were for the fuel costs for the university research reactors?

Mr. Lahs: Lifetime core, I think, was 5 to 6.2 million.

Commissioner Gilinsky: I'm sorry, I didn't hear you.

Mr. Lahs: Five to 6.2 million were for the lifetime cores. So you add a little bit more to that, so the major faction is the university reactors.

Chairman Palladino: What does it cost for your average unit reactor, the general university reactor?

Mr. Lahs: Let's see. If we used a number like $500 a plate for a plate type fuel, and we talk about two plates per rod, it's 18 times 500 times 20. Am I correct? Something like that? Cost of a reactor. Eighteen elements per reactor, the other two plates prominent? It's 356 times 500.

Chairman Palladino: So $128,000.

Mr. Lahs: 18,000.

Chairman Palladino: 100 and something thousand.

Mr. Lahs: Yes.

Chairman Palladino: Do you have more?

Mr. Benaro: No, that's it.

Chairman Palladino: I wonder if you could address the question that I posed at the beginning. You touched on it briefly, the comparative risk from a lifetime core.

Mr. Benaro: Okay. The lifetime core--I'll have to defer to someone else who might be expert in it.

As I understood the question you raised this morning on the lifetime core, the question was, if a lifetime core is in place and in reasonably frequent use, is it possible that the radiation dose, presumably, is so high that you couldn't steal it even if you had access to it.

Chairman Palladino: My question relates to whether or not the lifetime cores should be changed to high enriched to low enriched.

It's a of the fact that there is a lot at risk in terms of talking about opportunity and having a whole bunch of these transported in a prescripted period of time, such that it might attract terrorists.

Commissioner Gilinsky: You're saying irrespective of the radiation?

Chairman Palladino: I was not putting any conditions on it. As compared to the risk of that, I mean, the facility until the end of its life.

Commissioner Gilinsky: Well, you can obviously put more security on the transportation than is now being provided at the campus.

Chairman Palladino: I'd like to hear a comment on that. I heard Bob Burnette this morning. It was very valuable. I just thought --

Mr. Benaro: The only thing, as I understood your line of questioning in the following way, that when you have the fuel either unirradiated or modestly irradiated, in storage outside of pile, that it makes a certain target.

Now, if you don't have that, you have the fuel in pile, and there is a spectrum of reactors here. Some of them operate in such a way that you would get perhaps thousands of R from the fuel if you tried to steal it. You'd be killed immediately.

On the other hand, some are very low power machines. They have much smaller inventories, but they're low enough power that they aren't a whole lot different than a mildly irradiated fuel.

I think that's the spectrum. This rule presumes, at least the way it's structured, there is no mechanism for one to argue that since it is a lifetime core it is exempt.

It presumes that high enriched uranium, whether in pile or in storage, is to be removed from the field in an orderly way.

Chairman Palladino: I know that's what the rule says, and I am saying, well, is this the best thing to do on a lifetime core?

Mr. Lahs: In a lifetime core, with few exceptions, the trigger reactors are all generally less than 5 kgs, 5 kg inventory. So if that influences your thinking --

Chairman Palladino: Well, we were going to change it, weren't we?

Mr. Lahs: Yes. Further. So it gains whatever, converting 20 or 30 kilograms, you have to multiply it by the number of facilities that would be affected.

Commissioner Gilinsky: I suppose if you keep asking, you're bound to hit one.

Chairman Palladino: No, my questions are rather limited. The two background questions and this one are all I've got left. So these, I'm ready to vote.

Mr. Lahs: The threat drives whatever you decide to do, in my mind.

Chairman Palladino: That's what you say. The threat drives what we decide to do, and I'm trying to get a feel for the threat.

Mr. Benaro: The potential for the treat, as was said to you this morning, is that it's a matter of prudence.

It's a matter of prudence and the dispersion of high enriched uranium is the issue. Is high enriched uranium out there in the piles and in the storage facilities associated with them, to be removed or not.

Chairman Palladino: Is your answer saying that we should change those, regardless of any offsetting risk on ship?

Mr. Benaro: I could personally be comfortable with a lifetime core that had such a high radiation level that it would be virtually immediate death if you tried to pull it out and wrestle it out of the facility, you know.

But I'm not sure that many of them fit that bill. I just don't know. I'd have to ask some more expert person to say how many are in the category.

Commissioner Gilinsky: So you're talking about thousands of R.

Mr. Benaro: Yes, if the reactor lifetime core was such that its equilibrium one meter exposure is on the order of 1,000, 2,000, 3,000 R per hour, then there is just no way you can easily steal that.

Chairman Palladino: Does that suggest a different answer for different lifetime cores?

Mr. Benaro: Yes. That's my personal opinion. That is not the way the rule is set up.

Chairman Palladino: I know that's not the way the rule's set up.

Mr. Benaro: But when you get down to the smaller reactors, where you have smaller quantities, but it is still, nonetheless, low enriched uranium, I meant to say the low quantities of high enriched uranium at low radiation levels, lower radiation levels.

Chairman Palladino: Do you have any feel for which of these reactors you list would fall in the category of having thousands of Rs?

Mr. Benaro: I believe someone just pointed out that in order to have that high a radiation level it would be awfully tough to have a lifetime core.

In other words, it wouldn't be a lifetime core; it would be a reformable core.

Commissioner Asselstine: So that knocks out about 20 of them.

Mr. Benaro: Yes. My example may be a facetious example.

Commissioner Asselstine: Aren't there about 20 with lifetime cores?

Mr. Benaro: Yes, but they're mostly little ones, little reactors, and I don't think they fall into the category of reactors whose core is so irradiated as to be virtually lethal to look at, you know.

Chairman Palladino: So you're saying basically there are none of them.

Mr. Benaro: Yes, that's what I believe.

Commissioner Bernthal: So you're saying that if they are lifetime cores, as a practical matter, those tend to be very small.

Mr. Benaro: Those tend to be the smaller reactors.

Chairman Palladino: Having how much fuel, figure 235.

Mr. Lahs: Three kilograms.

Chairman Palladino: Three kilograms.

Mr. Lahs: Would that be right? You'd have to get the size.

Chairman Palladino: Well, it's easier to get them while--well, I don't know if it is. It may be easier to get them while they're in ship than to have to go to --

Commissioner Bernthal: They don't all ship them.

Chairman Palladino: I agree, except that if there is going to be a concentration of shipments, would it be easier to make 20 ships?

Commissioner Gilinsky: I think you've made your point, sir.

Chairman Palladino: I'm looking for an answer. I don't really have a point to make. I'm trying to decide what to do.

Commissioner Gilinsky: Just looking at this whole area, from my own point of view, if we get rid of the high enriched uranium, you're just getting rid of a lot of headaches, the possibility of first of all, people stealing the stuff, also to threats you don't have to worry about, you know, the whole notion of keeping tabs on them by constantly being in touch with intelligence agencies, the whole thing being a sort of an .

When the simple technical solution was really at a pretty modest cost, all things considered. It's not going to undermine the research program at these universities.

We heard from the University of Michigan. They managed this with relatively little pain. In fact, they seemed to have enjoyed it.

They said that going through the exercise of rearranging the reactor, that they learned a great deal.

After all, this was supposed to be an educational facility. It just makes a lot of sense on every count.

And if you look at the cost of mobilizing forces and protection and dealing with crank calls and all of that stuff, it just gets eliminated once that things--not the crank calls, but your assessment of what you have to do about it would change.

Chairman Palladino: You must not misunderstand. My leaning is very strongly towards getting the HEU down to LEU.

So I am trying on the lifetime cores, they are small quantities. How do they balance transportation versus the threat of theft in transportation where the--

Commissioner Gilinsky: You can certainly provide more security in transportation than is being provided now at the universities.

It seems to me that this is a program in which everyone comes out a hero. I mean, the DOE developed this terrific new fuel, the NRC is carrying out its responsibilities in eliminating a terrorist problem.

The universities would be contributing to increased public security and would be carrying on with their research program.

It's hard to think of a reason for not doing it.

Chairman Palladino: Any other comments? Questions?

Commissioner Bernthal: I would just comment that I don't disagree with any of that, but we also shouldn't be under any illusions.

I think that you dispense with a large part of the security requirements and, in fact, perhaps some additional security requirements, as we discussed this morning, because it's not at all clear to me that the principal risk is somebody trying to cart off this stuff to make a weapon out of it, which under any circumstance is not exactly like child's play.

The principal hazard probably still would just be a terrorist hazard, trying to make a mess, and that we want to avoid.

Commissioner Gilinsky: I agree with you. I think it's apparently true that it's much easier to do that, but if someone carted off quantities of this material and even if you knew who had taken it, there is no telling what hands it's going to end up in.

We may have a fairly long time to process it, and whatever the difficulties are of turning that material into weapons, let me tell you, a lot of government agencies are going to go straight into orbit.

Commissioner Bernthal: I'm not disputing that; my point is, if you ask yourself what the probability, the most likely event that you would have to take security precautions against, the extra security precautions will undoubtedly be necessary even if we take this action on HEU.

Commissioner Gilinsky: I must say, I see a very different problem in terms of the risk.

Commissioner Bernthal: We're assuming--what I'm saying is that I think there's an assumption of a fairly large number of highly educated groups that might target a reactor as compared to the number of relatively uneducated, nonsophisticated groups.

I'm just saying that I think the probability is higher that it would be the latter. That's not to disagree with anything that you said. I'm just simply saying that it does not obviate the necessity for some extra security measures.

Commissioner Gilinsky: I think there's going to be a hell of a lot more security in these places than there is and there should be in the future if they're going to be using highly enriched uranium.

The level of security that I would lay on to protect against them, say, making a mess is a far lesser one.

The thing about high enriched uranium is, it can just go anywhere in the world. Just like materials stolen aboard and here. I mean, you're talking about a lot of material which can do a lot of damage.

Chairman Palladino: Any comments?

Commissioner Bernthal: No, I think we've discussed that adequately.

Chairman Palladino: Is there any more questions on your part, Jim?

Commissioner Gilinsky: I must say I would, even though I might come out on it a little bit differently, I would just go forward with it just to get it out in the public, and also it would be good because my term is ending.

Chairman Palladino: Well, I recognize that, and that's why I want it discussed thoroughly. Just having seen it only last night, I guess on Friday, I do have a couple of areas where I'd like to work on specific and give some suggestions. And also I would subject any vote I would give to review of the issue and comments.

So I would not be prepared to vote today, but I'd be prepared to vote after the board talked some suggestions.

Still, my vote would be conditioned on the rest of the comments. But my inclination is to go this route.

So that I won't be losing my leverage, I want to get some word changes, but I think I've got to be honest about that.

Commissioner Bernthal: Mr. Chairman, since I see we're in danger of ending a meeting before an hour is up, and that's the precedent, let me ask a question.

Maybe you covered this, but I'm looking at the very last page in your presentation. I'm not sure what that means. "Potential avoided HEU exports." I've look at it for at least a minute--

Mr. Benaro: This is our chart that

you're looking at?

Commissioner Bernthal: Yes.

Mr. Benaro: This is actually out of a DOE report. It is, as I understand it, if you develop this fuel to replace HEU, its use in replacement would account for this fraction of the current HEU exports from the U.S., basically meaning that the advanced fuels would be required in order to get the really substantial fractions of that export quantity, that program.

The emphasis for the foreign exports appears to be much more advanced fuels are required to achieve the goals there than it is true for the U.S.

Commissioner Bernthal: So let me see, then, what you're saying is that we cannot use as an argument in the current case--I guess I use the word "current" advisedly--that there would be a significant impact on HEU exports, that could only come later with the advanced fuels. Is that what this is saying?

Mr. Benaro: Yes, in effect it's saying that our support--remember with our rule, we're dealing only with the U.S. licensees.

But as an example for the foreign, the prototype for the foreign--

Commissioner Gilinsky: Let's see. Some of the foreigners are moving toward lower enrichment but not 20%. In fact, some of them are doing it right now.

What we do here affects their incentive to move in that direction.

Mr. Benaro: Yes. That's a separate question.

Commissioner Gilinsky: It's 45%, I believe.

Mr. Benaro: Yes.

Commissioner Gilinsky: At one of the reactors. That's pretty significant, too, to do that at the larger reactors.

Commissioner Bernthal: The symbolic effect and practical, perhaps, of the demonstration here is a separate issue. I was just struck that we're seeing a chart here that talks about 500 kilograms of HEU exported, what, three years?

Mr. Benaro: I believe that's what it says.

Commissioner Bernthal: And that we need advanced fuels to take care of most of that.

Commissioner Asselstine: But I think the IP paper does emphasize that what happens domestically, it will have significant impact on willingness of those other countries to continue to work on the conversion approach and to reduce the enrichment levels of their own reactors.

Chairman Palladino: We had advertised this as a possible vote. I did express my view that I am not prepared to vote on this paper at this time.

I would be prepared to indicate my sympathy with the approach and would like the opportunity to submit some suggestions.

This should be done within the week, let's say.

Commissioner Asselstine: For myself, I'd be prepared to go ahead with the staff's package today, but if you want the opportunity to make a few suggested modifications, that's acceptable to me.

Commissioner Gilinsky: I would approve it, too, as I say, and hope that this process will conclude before the end of the month.

Chairman Palladino: I'm counting on that.

Commissioner Roberts: I would be curious as to what you may come up with in modifications outside of waiting 'til we get the ACRS evaluation.

Chairman Palladino: Incidentally, even if I move before the ACRS, I would condition it on the ACRS comments.

Commissioner Bernthal: We already discussed that with the ACRS and the point is that their charge principally is one of evaluating safety impact, and that's not the principal question here. In fact, I guess it's not a question here, I should say.

Commissioner Gilinsky: I must say I didn't think there was any need to send it to the ACRS, but anyway, it's been done.

Commissioner Bernthal: The value of sending it to the ACRS, though, is that a lot of these guys do have practical experience with research reactors that certainly no one else in this agency has.

Even though it's not directly within their charge, they ought to provide some valuable, practical insight, I think.

Chairman Palladino: So what's your view?

Commissioner Bernthal: I didn't understand what your question is. Is it to vote today?

Chairman Palladino: To vote today.

Commissioner Bernthal: I guess if there are going to be changes suggested, I'd just as soon see the changes. Otherwise, we're going to have a non-vote today.

Chairman Palladino: I'll try to get my changes to you within a week and maybe sooner.

Commissioner Bernthal: Okay.

Chairman Palladino: I expressed my general sympathy with the approach taken. I did want to clarify the lifetime core issue for myself. Whether or not I'll have comments on the lifetime core, I can't determine if I'll have any.

Commissioner Bernthal: I don't have any problem with moving ahead on this fairly expeditiously. It's not clear at all to me that you'd come out ahead, getting back to an earlier point, by removing the comment on the financial requirement here.

Chairman Palladino: It's more basic than that.

Commissioner Bernthal: They can cut either way and I understand the logic that attaches to your position.

Chairman Palladino: See, our reason for doing this is rather weakly stated, to say the least.

Commissioner Bernthal: And you're saying that somehow the financial part weakens it further, I suppose.

Chairman Palladino: Yes. I'd like to see--I think we have a better rationale than given here. Whether I fouled it up by suggesting it, I don't know, but I'd like to try it.

Commissioner Bernthal: But the whole rationale for this thing is rather complex, and it involves symbolism and certain practicalities. I'm inclined to leave the statement of financial requirement in there.

It's not clear at all which way that cuts. I don't know whether it will happen faster and easier if it's in or out, quite frankly.

Commissioner Gilinsky: Well, the basic rationale is to get material out of which you create bombs off the campus.

Commissioner Bernthal: Oh, sure. I understand. That's not the issue.

Chairman Palladino: Let's see what I heard. I heard a willingness, at least on Jim's part and Tom Roberts' part, to wait 'til I get my suggested changes, which I promised within a week.

I also sense that the majority of the commission is quite sympathetic to the proposal, and the only thing is fixing the report.

Commissioner Roberts: Yes, I will say the same thing I said this morning in another context, that another value of our acting quickly on this and definitively is that then it will pass from a risky position right now of excessive public attention, I think, and that in itself carries risks with it, and I'd like to take care of it so that we no longer run that risk.

Chairman Palladino: I do think we have the responsibility to do something on the upgraded security, and we will address that, I hope, in a timely fashion.

Commissioner Asselstine: You know, if we do decide in a week or so to go forward with this package, I also think perhaps we ought to consider writing to the Health, Science and Technology Committee about the cut of the $700,000 and the impact that that's going to have in the RERTR program and how that fits in with this proposed rule as well, because it seems to me that's such a small amount of money, and yet there's such a significant adverse impact on the program. But that's worth emphasizing our concerns on it, particularly if we're prepared to go forward with the approach of this rule, which I am.

Chairman Palladino: Yes, I think it would be helpful if you put that in the form of a memo and we could take it up.

Is there further action the commissioners want to take at this time? Okay. Then we thank the presenters and we stand adjourned.

(Whereupon the meeting was adjourned at 3:10 p.m.)

CERTIFICATE OF PROCEEDINGS

This is to certify that the attached proceedings before the NRC COMMISSION

In the matter of: Discussion on Proposed Rule on LEU/HEU Fuel.

Date of Proceeding: May 31, 1984

Place of Proceeding: Washington D.C.

were held as herein appears, and that this is the original transcript for the file of the Commission.

Joe Newman
Official Reporter - Typed

Joe Newman/DJB
Official Reporter - Signature

APPENDIX 5

PUBLIC COMMENTS

Congress of the United States
House of Representatives
Washington, D.C. 20515

January 26, 1984

The Honorable Nunzio Palladino
Chairman
Nuclear Regulatory Commission
Washington, D.C.

Dear Mr. Chairman:

We commend the Nuclear Regulatory Commission's action on Commissioner Victor Gilinsky's initiative to replace highly enriched uranium with low enriched, non-weapons usable uranium in domestic research reactors. We understand, however, that the proposed conversions might cover only four or five of the twenty-five research reactors which presently utilize highly enriched uranium fuel at universities in the United States.

For the reasons set forth below, we believe that the conversion to low enriched uranium (LEU) at all domestic research reactors at which it is technically feasible should occur.

First, we firmly believe that the unnecessary use anywhere of nuclear explosive materials such as highly enriched uranium presents risks which can and should be avoided.

Second, our conversion of domestic research reactors to LEU would set an important example and establish U.S. leadership in the conversion of research reactors throughout the world to non-explosive fuels. As you know, there has been consistent Congressional support for such conversions in the form of support for the Reduced Enrichment for Research and Test Reactor (RERTR) program. Moreover, we have introduced legislation now pending before Congress that includes provisions which encourage and mandate the export of low enriched research reactor fuels by the United States.

Finally, we also wish to make clear that should the Commission rule require the conversion of domestic university research reactors, we will seek to provide the necessary funds to implement the conversion and to return highly enriched uranium fuel to Department of Energy facilities.

Thank you for your consideration of our views.

Sincerely,

Richard Ottinger

Richard L. Ottinger
Chairman
Subcommittee on Energy
Conservation and Power
Committee on Energy and Commerce

Ed Markey

Edward J. Markey
Chairman
Subcommittee on Oversight
and Investigation
Committee on Interior
and Insular Affairs

Howard Wolpe

Howard Wolpe
Member
Subcommittee on International
Economic Policy and Trade
Committee on Foreign Affairs

Congreſs of the United States
House of Representatives
Washington, D.C. 20515

March 23, 1984

Mr. Nunzio Pallidino
Chairman
Nuclear Regulatory Commission
1717 H St., NW
Washington, D.C. 20555

Dear Mr. Chairman:

It is my understanding that the Nuclear Regulatory Commission is currently considering a rule to require those research reactors it licenses to convert from high-enriched uranium (HEU) to low-enriched uranium (LEU).

The University of Missouri at Columbia in my district operates a research reactor using HEU. I am writing to request that the University be permitted continued use of HEU. An exemption from the proposed rule for educational institutions is needed for several reasons.

Converting to LEU could cause scientific and financial difficulties. The reactor has helped the University contribute significantly to advances in medicine, physics and materials science while training the next generation of nuclear engineers.

I am especially concerned that a forced conversion to LEU will degrade America's research capabilities. A very high emittance machine cannot, I understand, be converted to LEU without great expense and a considerable loss in experimental value. The director of the University reactor facility, Dr. Robert Brugger, has informed me that conversion to LEU will render the reactor useless for many experiments.

Your prompt attention to this matter is appreciated.

Sincerely,

Harold L. Volkmer
Member of Congress

HLV/cs

TEXAS A&M UNIVERSITY
COLLEGE OF ENGINEERING
COLLEGE STATION TEXAS 77843-3133

DEPARTMENT OF NUCLEAR ENGINEERING
(409) 845 4161

8 May 84

The Honorable Nunzio J. Palladino
Chairman, Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Utilization of LEU Fuels in U.S. University Research Reactors

Dear Chairman Palladino:

Because I am interested in the continued viability of research reactors in the United States, I would request that you consider the situations posed in this letter prior to publication of a rule pertaining to use of LEU fuels in research reactors. However, due to uncertainties that now exist and the problems these uncertainties can cause, I would also request that the commission consider rapid publication of a guidance document that pertains to the timetable for conversion to LEU. Please understand that the views expressed in this letter are not necessarily those of the staff of the Nuclear Science Center, the faculty and staff of the Nuclear Engineering Department, the membership of the Reactor User's Committee of which I serve as chairman, or any other organizations of Texas A&M University.

The 1MW TRIGA FLIP-fueled research reactor at Texas A&M is one of the most highly utilized 1MW facilities in the United States. However, recent events that have occurred here illustrate the confusion that reigns regarding the requirement for conversion to LEU fuels. The Nuclear Science Center reactor is currently under review for "deactivation" due to a misunderstanding or misinterpretation of these requirements. While it is common for facilities like the Nuclear Science Center to face program reviews, the cost of fuel conversion has not in the past been used for justification of a shutdown. It appears that the conversion costs will be considered in further administrative reviews on this campus and I am sure other Universities will follow if they are not already incorporating "possible fuel conversion costs" in their reviews. Please consider the fact that manpower costs for preparation of FSAR's, verification of parameters and preparation of all license related submittals is also considered in these assessments.

Today there is concern in many organizations about the lack of students in nuclear engineering programs throughout the United States. Much of this number decrease can be attributed to the negative media "tilt" regarding the nuclear industry. Shutdown of even a few university research reactors will increase the level of negative feedback students receive regarding opportunities in the nuclear industry. Shutdown of high quality university research reactors will also lead to production of a "lower quality" graduate due to the lack of a reactor for use in academic training of these individuals.

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While the overall tone of this letter is rather negative, please note that for those reactors where use of LEU fuel is technically feasible (without degradation of performance capabilities) I fully support the conversion to LEU fuels. I would hope that this letter indicates some of the problems that financially strapped universities are facing. Thus, conversion should only be required if adequate federal government support is provided and this fact should be so stated in the proposed rule.

Sincerely,

Gerald A Schlapper

Gerald A. Schlapper, Ph.D., P.E.
Assistant Professor

GAS/kls
cc: Dr. C. Erdman
Mr. D. Feltz

University of Notre Dame
Notre Dame, Indiana 46556

May 23, 1984

Dr. Joseph N. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Palladino:

This letter is being written to express my concerns, both as an individual and as Chairman of the Education Division of the American Nuclear Society. These concerns are shared by Dr. Paul Turinsky, Professor and Chairman of Nuclear Engineering at North Carolina State University, Chairman of the Nuclear Engineering Department Heads Organization, and by Mr. A. Francis DiMeglio, Rhode Island Nuclear Science Center, Chairman of the Research, Test, and Training Reactors Group, both of whom I consulted in preparing this letter.

Our concerns arise from the Commission's apparent departure from its own procedures in its haste to draft and issue a rule with regard to conversion of University Research Reactors from HEU to LEU fuels without fully considering the impact of the proposed rule or alternative actions which may more effectively meet the concerns which gave rise to the proposed rule. An even greater and more unsettling departure from its normal procedure is the prospect that the Committee will impose "voluntary" measures for increased security at non-power reactors without any opportunity for discussion of the costs and benefits associated with that action. Some of these impacts and alternatives will be discussed at the American Nuclear Society meeting in New Orleans June 4 and at a meeting of the ACRS Subcommittee on Safeguards on June 12.

Commission policy, as set forth in NUREG-0885, we believe, calls for a systematic evaluation of risks and benefits associated with a proposed generic rulemaking. The proposed rule, in our view, warrants a more systematic look at the impacts and social costs of the proposed action and a more careful evaluation of possible alternative actions.

The cost-benefit analysis contained in the Regulatory Analysis supporting the HEU/LEU rulemaking has been described by some NRC staff as inadequate. Some other points which were raised with only casual and unsubstantiated discussion in staff presentations are:

1. The probable loss of several U.S. research reactors due to an inability to fund the expense of extended litigation provoked by the conversion to LEU. The social impact of such a loss could involve a reduction in the number of training facilities and programs available in the United States with a concomitant reduction in the number of students in those

programs. (This at a time when NRC and INPO studies estimate a need for more than 5,000 trained people for replacement and upgrading of operating staffs in U.S. power reactors.) The resulting curtailment of both physical and medical research programs in the U.S. may accelerate the development of these capabilities offshore, a development which may not be in the national interest.

2. From a risk assessment point of view, a prudent national policy to limit the flow of highly enriched material would devote maximum effort and resources to those situations where the amounts of material involved are largest and the levels of shipping and handling are high. A qualitative ranking of HEU uses and users suggests that low-power research reactors are at the bottom of such a list, with medium-power university reactors next lowest. A near-term changeover from HEU to LEU fuel in small research reactors may indeed "set a good example". It will not, however, reduce the diversion risks from the much larger inventories and material flows associated with larger, non-university reactors. These risks, it appears, will continue for several years (possibly four or five), regardless of the timing required of domestic university reactors. This consideration indicates a need to reevaluate the pace (in some cases, the need) for conversion to LEU. It is important that these conversion efforts not divert the staff and resources of DOE, NRC, and the State Department from the much larger non-domestic risks.

3. One of the apparent motives for NRC action in this area is the rise in terrorist activity and the postulation of highly coordinated, internationally supported, terrorists with substantial resources. Terrorists might have as objectives any combination of five items:
    a. personnel casualties;
    b. facilities damage;
    c. dispersion of radioactive material;
    a. diversion of HEU fuel; and
    e. symbolic activities aimed at raising and manipulating public alarm.

    We suggest that the proposed conversion to LEU fuel does not address or significantly impact items a through d, and appears to enhance the attractiveness of item e.

4. A systematic risk evaluation of potential diversion from small research reactors by a neutral, but well-informed, panel appears to us to be a necessary prelude to any rulemaking. A policy of reducing the tonnage flows of HEU in international commerce appears prudent, since the amounts of material in some single shipments and single locations appear

to be more than ample to make one or more nuclear explosive devices. The implication, however, that domestic research reactors present a comparable risk deserves a more careful evaluation. (Note that low power research reactors contain only a fraction of the amount of material required to make a plausible nuclear explosive.)

5. It may be that the Commission has substantiated information on risk exposures which are not known to universities, and which provide a sufficiently compelling basis for the "as soon as technically practical" guideline provided to the staff for conversion to LEU fuel. If such compelling evidence exists (particularly since conversion does not actually address most of the risks), we believe it proper that the Commission and/or appropriate security agencies share this information with affected members of the university community (on a classified basis if necessary). If such compelling evidence does not exist, we reiterate our belief that it is appropriate for the Commission and its staff to more carefully investigate the alternative actions and impacts noted above.

6. The $15 million expense, presumably to be funded by DOE, for HEU/LEU conversion envisioned in NUREG/CR-3666 will have no discernable educational benefit. The same amount used to upgrade obsolescent university laboratories would have a major impact on the quality of engineering education in this country. Absent the compelling evidence mentioned in (5) above, the Commission should not only consider whether the proposed measures are possible, but also whether they represent a reasonable use of scarce federal and university funds.

We request that at its meeting May 31, 1984 the Commission not take action to have the proposed HEU/LEU rule published for public comment, but rather follow its normal procedure of waiting for the report of the ACRS on the proposed rule before taking further action. Further, we request that the Commission follow its normal rulemaking procedure and not impose "voluntary" security requirements on university reactors in lieu of a more deliberate rulemaking procedure.

Sincerely,

John Lucey

John W. Lucey
Chairman
Education Division, ANS

cc: ACRS Subcommittee on Safeguards
A.F. DiMeglio
P. Turinsky

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone: (312) 352-6611 • Telecopier: (312) 352-0499 • Telex: 254635

June 11, 1984

The Hon. Nunzio J. Palladino
Chairman, United States Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Chairman ~~Palladino~~ Joe:

Conversion of Fuel Elements of Non-Power Reactors
from Highly-Enriched to Low-Enriched Uranium

As you may know, the American Nuclear Society sponsored a special session at its recent New Orleans meeting concerning the conversion of non-power reactors from the use of high enriched uranium fuel to low enriched uranium fuel. This session generated considerable discussion and concern because of the present approach by the NRC which effectively mandates conversion of all the non-power reactors to low enriched uranium. We believe that this conversion will most certainly result in the shut down of several of the operating reactors.

During the discussion, considerable pertinent evidence, not covered in past analyses, was presented concerning the relative diversion risks of various types of facilities which utilize high enriched uranium. From this evidence, it is clear that the risks of diversion from these non-power reactors is minimal. Based on this information (presented in the attached paper) we feel that a more systematic and thorough analysis of these risks would be prudent before issuance of a proposed rule.

The American Nuclear Society (ANS) offers its technical resources to assist the Commission in any way possible.

Sincerely,

Joe

Joseph M. Hendrie

JMH:eh
encls.

UNION CARBIDE CORPORATION P. O. BOX 324, TUXEDO, NEW YORK 10987
MEDICAL PRODUCTS DIVISION TELEPHONE NUMBER: (914) 351-2131

June 12, 1984

U. S. Nuclear Regulatory Commission
Washington, DC 20555

Gentlemen:

Union Carbide has a vital interest in the issue of HEU to LEU conversion of research reactor fuel and we would like to take the opportunity provided by this ACRS meeting to reiterate our concerns about the rule which the NRC is considering for mandating this conversion to all research reactors.

The enclosed correspondence provides a handy reference to previous statements which we have made on this issue. The concerns which were expressed therein have not changed and we request that you consider them in your deliberations before you formulate your recommendations on this issue. The highlights of our concerns are summarized at this time for emphasis.

- The Union Carbide Nuclear Reactor operates primarily to produce shortlived medical diagnostic radioisotopes.
- The reliable supply of approximately one half of the world supply of reactor produced medical isotopes depends upon this reactor facility.
- Any conversion will have to take place incrementally over a relatively long period to assure the uninterrupted supply of radioisotopes.
- Converting the fuel of this reactor will affect the core operating characteristics and ultimately the isotope production process.
- It is important to minimize this effect as much as possible. The thermal-hydraulic characteristics and metal/water ratios remain unchanged with the U_3Si_2 fuels of U densities greater than 4.5. These higher density loadings also offer operating cycles and useful fuel life comparable to the current HEU fuels.

- Tests to date indicate that the thermal neutron flux/power ratio is decreased in LEU cores and this will have adverse technical and financial consequences on the isotope production process.
- Currently used HEU fuels have been tested comprehensively under accident conditions. LEU fuels have not been qualified so.
- The financial impact of relicensing the LEU fueled reactor will be significant. If this conversion is mandated, the total cost of conversion should be subsidized.

Thank you for this opportunity to be heard. We still believe that the precautions against unauthorized diversion of SNM that have been taken over the past several years which involve a combination of basic security measures, adequate self-protection (particularly in the higher powered research reactors) and comprehensive accountability practices have proven to be effective. We don't know why this should not continue to be so.

Thank you for your continued consideration.

Very truly yours,

JMcGovern

James J. McGovern
Business Manager
Radiochemicals

JJMcG:js

Lahs   Mirogue

UNIVERSITY OF CALIFORNIA, LOS ANGELES   UCLA

BERKELEY · DAVIS · IRVINE · LOS ANGELES · RIVERSIDE · SAN DIEGO · SAN FRANCISCO   SANTA BARBARA · SANTA CRUZ

OFFICE OF THE CHANCELLOR
LOS ANGELES, CALIFORNIA 90024

June 14, 1984

Dircks
Roe
Rehm
Stello
Davis
Denton
GCunningham

T. Rehm
3/7

Mr. Nunzio J. Palladino, Chairman
Office of the Commissioner
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Commissioner Palladino:

I write to inform you that I have decided to withdraw the application for renewal of the license for the UCLA research reactor (Docket No. 50-142; License No. R-71), currently pending before the Atomic Safety and Licensing Board, and intend to initiate steps to decommission the reactor. I have today informed the Board of Regents of the University of California of this decision, and have asked the University's attorneys to terminate the relicensing proceedings.

My decision to decommission the reactor four years after submitting an application for license renewal was reached after extensive consultation with academic administrators on the campus, and solely as a result of our examination of the changed circumstances affecting the academic benefits and escalating costs of continued operation of the reactor facility. The use of the fission reactor by the School of Engineering and Applied Science at UCLA for teaching and research purposes has declined in the years since we filed for license renewal. During this same period the costs of the reactor have risen dramatically. We have also had to take into account uncertainties in the future of research reactor programs. In the last several months the Commission seems to have moved rapidly in the direction of requiring research reactor facilities to convert from the use of high-enrichment uranium to low-enrichment fuel, with associated costs that are, at present, unknown.

The timing of our review of the fission reactor program and decision to decommission is related to the appointment, last summer, of a new Dean of Engineering, who has had to reevaluate the School's programs and priorities in light of available resources, and the current maintenance status of the reactor. As we recently informed the Commission, the UCLA reactor is out of operation, pending correction of a sticking control blade. Correction of the problem will require disassembly of the reactor core, and prudence dictates that we reach a decision on the future of the reactor now, before committing personnel and resources to such a major maintenance effort. We have concluded that the potential expense of maintenance, fuel conversion (perhaps involving another relicensing proceeding), and ongoing operation of the reactor simply cannot be justified in light of its declining importance to our academic programs.

CY: ROSS
KELBER
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I regret that a final resolution by the Licensing Board of all the issues raised in the proceedings has not been obtained. Nonetheless, we are pleased to note that the technical staff of the Commission, which over the past several years has exhaustively reviewed our license renewal application, concluded in its published evaluations that the UCLA reactor has been operated safely throughout its 24-year history and would be expected to do so during the proposed renewal period.

We appreciate the assistance and cooperation of the staff of the Commission, particularly during the relicensing period, and look forward to working with them in carrying out a decommissioning plan.

Sincerely,

Charles E. Young

Charles E. Young
Chancellor

cc: Director of Nuclear Reactor Regulation

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

June 18, 1984

Honorable Nunzio J. Palladino
Chairman
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Palladino:

SUBJECT: ACRS REPORT ON PROPOSED RULE FOR LIMITING THE USE OF HIGHLY ENRICHED URANIUM IN DOMESTIC RESEARCH AND TEST REACTORS

During its 290th meeting, June 14-16, 1984, the Advisory Committee on Reactor Safeguards reviewed a proposed rule for limiting the use of highly enriched uranium in research and test reactors and a plan to increase security measures at nonpower reactors that use high-enrichment fuel. These matters were considered also during a Subcommittee meeting in Washington, D.C. on June 12, 1984. During our review, we had the benefit of discussions with representatives of the NRC Staff, affected users, and advocates of reduced availability of highly enriched uranium fuel. We also had the benefit of the documents referenced.

With regard to the proposed rule limiting the use of highly enriched uranium in domestic research and test reactors (contained in SECY-84-211), we believe it would be more appropriate to base the proposal on national policy as articulated in the Nuclear Nonproliferation Policy Act of 1978 than to try to tie it to an unidentified threat. If the proposal is based on national policy, it would be appropriate for the government to pay the costs of conversion from high-enrichment (HEU) to low-enrichment uranium fuel (LEU), including such costs as the licensees may incur to accomplish the conversion. The conversion should be made in a gradual and orderly manner as funds and fuels become available. The rule should provide the licensees with the option of conversion to LEU or retaining HEU and meeting appropriate security requirements.

If, as a consequence of changes needed to effect a conversion, a license amendment is required, then a hearing with the opportunity for public intervention is possible. Before the Commission adopts a rule which might permit unrestricted intervention, we recommend that the Commission obtain an evaluation of the course, nature, costs, and other relevant aspects of previous contested hearings involving nonpower reactors to determine if the hearings are serving their intended function effectively. It may be that the rules regarding hearings involving low power research reactors should be different than those for power reactors.

The exceptions in the proposed rule which would permit special purpose reactors to continue to use highly enriched uranium fuel are appropriate and should be retained.

With regard to the plan and schedule to increase security measures at nonpower reactors that use highly enriched uranium fuel, we find no objections to the proposals. We see no need to proceed on an expedited schedule.

Two of the Committee members who participated in this review are associated with affected institutions listed in the draft public announcement of this rule. Because they are rendering advice of a general nature from which their employers will gain no preference over others, they are not required to refrain from participating in this matter. Dr. M. W. Carbon did not participate in this review.

Sincerely,

Jesse C Ebersole

Jesse C. Ebersole
Chairman

References:

1. Rulemaking Issue (SECY-84-211) from William J. Dircks to the Commissioners, Subject: Proposed Rule for Limiting the Use of High-Enriched Uranium in Research and Test Reactors, dated May 22, 1984
2. Rulemaking Issue (SECY-84-216) from William J. Dircks to the Commissioners, Subject: Security Measures at Nonpower Reactors, dated May 25, 1984
3. Policy Issue (SECY-84-220) from William J. Dircks for the Commissioners, Subject: Research Reactor Fuel Conversion Developments and Related Issues, dated May 30, 1984
4. Report to NRC Commissioners, "Weapons-Grade Uranium on Campus - The Need to Convert Research Reactors to Lower Enrichment Fuels," by Daniel Hirsch, Stevenson Programs on Nuclear Policy, University of California, Santa Cruz, dated January 27, 1984
5. Letter from Donald E. Feltz, Nuclear Science Center, Texas A&M University System, to John C. McKinley, Advisory Committee on Reactor Safeguards, dated June 12, 1984, Subject: ACRS meeting of June 12, 1984 regarding proposed rule on HEU
6. Letter from James J. McGovern, Business Manager, Radiochemicals, Union Carbide Corporation to U. S. Nuclear Regulatory Commission, Subject: Issue of HEU to LEU conversion of research reactor fuel, dated June 12, 1984
7. Report by Edwin L. Zebroski, Energy Study Center, Electric Power Research Institute, "Relative Diversion Exposures of High Enrichment

Uranium: Relation to University Research Reactors," dated June 4, 1984

8. Statement of William R. Mowry, License Administrator, GA Technologies, Inc. before the ACRS Subcommittee on Safeguards and Security dated June 12, 1984
9. Statement of Dr. David W. Hafemeister Before the NRC Regarding the Need to Convert Domestic Research Reactors from Highly Enriched to Low-Enriched Uranium Fuels, dated June 12, 1984
10. Statement of Paul L. Leventhal, Nuclear Control Institute, Before the Subcommittee on Safeguards and Security, ACRS, Regarding the Need to Convert Domestic Research Reactors From Highly Enriched to Low-Enriched Uranium Fuels, dated June 12, 1984

FROM:
ACRS: Jesse C. Ebersole

TO:
Chairman Palladino

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ACRS Report on Proposed Rule for Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

SPECIAL INSTRUCTIONS OR REMARKS

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EXECUTIVE DIRECTOR FOR OPERATIONS
PRINCIPAL CORRESPONDENCE CONTROL

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North Carolina State University
School of Engineering

Department of Nuclear Engineering
Box 7909 Zip 27695-7909

June 18, 1984

Dr. Nunzio Palladino
Chairman, Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Palladino:

On June 12 I testified on behalf of the Nuclear Engineering Department Heads Organization (NEDHO) on the proposed rules for HEU to LEU conversion and augmented security at non-power reactors at an ACRS subcommittee meeting. A copy of the transparencies I used is attached.

As I stated at the December NRC Commissioner's meeting on this subject, NEDHO believes the HEU to LEU conversion rule is unwarrantead. The benefits (reduced division risk) are small, while the costs (shutdown of some university reactors) are large. Dr. Zebrowski's paper, forwarded to you under separate cover, places the benefits in the proper perspective. The likelihood of university reactors shutting down arises due to the uncertainties in the regulatory process and funding. NEDHO does not believe a rule can be written to deter determined intervenors from causing a lengthy and expensive regulartory hearing. The recent decision by UCLA to permanently shutdown their reactor confirms this belief that the length and cost of the regulatory hearing versus merit of the case will result in some university reactors shutting down. NEDHO also cannot see how the availability of federal funds for conversion can play a significant role in the rule's implementation. If there is a conversion rule, its existence indicates a safety problem that must be addressed with or without funds available. As you know, the House has removed FY85 funds for conversion.

Regarding the proposed augmented security rule, NEDHO's membership has not had adequate time to review the proposed rule. Since the proposed rule indicates that current security requirements are adequate, NEDHO believes that the rush to implement augmented security requirements should be slowed down. This will allow the NCR staff, licensees and other interested parties to have adequate time to reflect upon this matter. Let me stress that NEDHO has no opinion at this time on whether the proposed augmented security rule is needed and properly formulated.

Sincerely,

Paul J. Turinsky
Chairman, NEDHO

PJT:dcr

Enclosure

cc: Dr. John Lucey
Mr. A. Francis DiMeglio

841391

ACRS Subcommittee Presentation

Nuclear Engineering Department Heads Organization (NEDHO)

Comments On

Proposed Rules on HEU to LEU Conversion and Improved Security Measures at Non-Power Reactors

Presentor: Paul J. Turinsky
Chairman - NEDHO
(North Carolina State University)

June 12, 1984

HEU TO LEU CONVERSION

- UNIVERSITIES WISH TO BE COOPERATIVE IF
  - LICENSING RISKS
  - FINANCIAL RISKS

  CAN BE CONTAINED.

- UNIVERSITIES OPINION IS CONVERSION IS "NICE" BUT "NOT NECESSARY" THING TO DO.

COST/BENEFIT EVALUATION DOES NOT SUPPORT PROPOSED RULE.

- BENEFIT IS SMALL

  LOW LIKELIHOOD OF SIMULTANEOUS MULTI-REACTOR DIVERSION AND SUBSEQUENT WEAPON PRODUCTION WITHOUT LAW ENFORCEMENT INTERVENTION.

- COST COULD BE HIGH.

  LOSS OF REACTORS WITH ADVERSE IMPACT ON TEACHING, RESEARCH AND SERVICE IN MANY SCIENTIFIC AREAS.

  NEGATIVE PUBLICITY ASSOCIATED WITH LICENSING WILL ADVERSELY IMPACT NUCLEAR ENGINEERING ENROLLMENTS.

  REACTORS ALREADY UNDER UNIVERSITY ADMINISTRATION PRESSURES SINCE OPERATING COSTS HIGH AND NE ENROLLMENT WAY DOWN VERSUS OTHER ENGINEERING DISCIPLINES.

- PROPOSED RULE OR ANY MODIFICATIONS CANNOT ADEQUATELY ADDRESS LICENSING AND FINANCIAL RISKS.
  - LICENSING

    LIKELIHOOD OF UNREVIEWED SAFETY QUESTIONS SURFACING OR TECH SPEC MODIFICATIONS IS UNKNOWN.

    GENERIC RULE (IF FOUND APPLICABLE) COULD BE BASIS FOR INTERVENTION WITH REGARD TO APPLICABILITY TO A SPECIFIC REACTOR.
  - FINANCIAL

    IF RULE ADOPTED, FINANCIAL LIMITATIONS WILL NOT PLAY A ROLE SINCE ADMITTED "PROLIFERATION PROBLEM".

    HOUSE JUST REMOVED FY85 CONVERSION FUNDING.

    WHO PAYS ATTORNEYS' FEES FOR PROTRACTED LITIGATION?

· Specific comments on Proposed Rule language

Item	Comment
(b.3)	"Unique purpose" licensing will discourage "unique research" due to licensing concerns.
(c.2)	Replace "acquisition" with "date of order"
(c.2)	Fuel acceptable to the Commission may not be acceptable to the manufacturer (warranty) and university (pulsed fuel)
(c.3)	Tough to imagine how NRC will determine what enrichment corresponds to "unique purpose" breakpoint
(d.2)	Don't see how financial support can play a role if a "proliferation problem" exists as rule would imply
(3)	Good intent to simplify licensing but will not likely deter determined intervenors.

AUGMENTED SECURITY

- NEDHO MEMBERSHIP HAS HAD LIMITED OPPORTUNITY TO REFLECT UPON PROPOSED RULE [APPARENTLY SAME COMMENT APPLIES TO STAFF].

  FOLLOWING COMMENTS MORE THE PRESENTOR VERSUS NEDHO MEMBERS.

- RULE APPEARS MOTIVATED BY RECENT INTERNATIONAL TERRORISTS' ACTIONS AND INADEQUATE INTERNATIONAL INTELLIGENCE.

  IS NOT DOMESTIC INTELLIGENCE BETTER?
  HAS MARGIN OF CONSERVATISM BEEN REALLY REDUCED?

- EMPHASIS SHIFTING FROM DETECTION TO PREVENTION.

  MAJOR POLICY SHIFT REQUIRING CAREFUL CONSIDERATION.

- RULE HAS SUCH URGENCY IMPLIED THAT IT INDICATES AN IMMEDIATE THREAT. HOWEVER, JANUARY 25TH STAFF MEMO INDICATES THE OPPOSITE.

- HASTY "VOLUNTARY" IMPLEMENTATION, WITH ORDER THREAT, WOULD DENY LICENSEES AND OTHER INTERESTED PARTIES WITH OPPORTUNITY FOR INPUT.

- COST OF IMPLEMENTING RULE IS UNCLEAR SINCE LIMITED ANALYSIS AND RULE SPECIFIC REQUIREMENTS NOT CLEAR. LIKELY UNIVERSITIES AND NOT DOE WILL PAY COSTS.

RECOMMENDATIONS

RECOMMEND ANALYSIS OF COSTS AND BENEFITS BE COMPLETED, OBTAINING LICENSEES' INPUTS, BEFORE DECISION ON NEED FOR RULE BE MADE.

IF SUBSEQUENTLY DETERMINED NEED EXISTS, IMPLEMENT VIA NORMAL RULEMAKING.

- Specific comments on Proposed Rule language.

Item	Comment
Augmented Minimal Protection	
(b)(d)(e)(f) & (g)	Vague and what is specifically required is unclear.
(e)	Access barriers may have adverse effect on teaching (fuel loading exp.) and research (insertions into core).
Additional Protection of Category I Facilities	
(a)	Agree with staff that submittal of plan when rulemaking in progress is wasted effort.
(b)(c)	Would not expect to be a problem to implement.
Transportation	
(3)	Preferred mode if need to do something. "Interesting" basis.
Implementation	"Voluntary" with threat of order is not voluntary. Process does not provide licensee with ample opportunity for input. No immediate urgency hence normal rulemarking is recommended.

GA Technologies

GA Technologies Inc
P O BOX ~~[illegible]~~ 85608
SAN DIEGO CALIFORNIA 92138
(619) 455-3000

19 June 1984

Dr. Nunzio J. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Palladino:

I have tried unsuccessfully to reach you or your technical assistant, Dan Garner, to discuss troublesome aspects of the proposed rule on Conversion from HEU to LEU for non-power reactors. In this letter I have set forth considerations that I hope will be helpful to you in your deliberations. Under separate cover, President Agnew has sent letters individually to the other Commissioners whom he was able to contact directly this date.

We are quite concerned that this proposed rulemaking will fail in its espoused international objective and through incumbent costs, borne mainly by existing facilities (the order of $1-million or more per facility), will do great harm to the already beleaguered U.S. research community, consisting of government, university, and privately-owned facilities. We further believe that it is an unreasonable policy which causes only NRC licensed facilities, despite costs, to cease their utilization of HEU while no such requirement is mandated upon reactors operated by the government agencies.

It is paramount that NRC's policy for reducing enrichment in existing non-power reactor fuels follow these precepts.

1. Immediate conversion of HEU to LEU should not be required for existing U.S. reactors.

2. If and when a change to LEU is required, it should be done in moderate steps, e.g., at normal refueling periods, upon major facility upgrade involving core redesign, or at construction of a substantially new reactor facility, and

3. Licensees shall not be exposed to significant relicensing processes or associated costs as a result of replacing HEU fuels with LEU fuels to meet a national objective and shall be protected to the extent possible from intervenor actions.

We believe that precepts 1 and 2 should be NRC policy for a number of reasons.

(a) It is evident that no government agency or collective group has been or is now currently willing to fund directly the subject reactor conversions especially when considering the nebulous benefits and the pressing need for funds in other more tangible projects, many of which are carried out by universities throughout the nation; clearly reserve unirradiated HEU fuel should be kept in properly guarded storage.

(b) The HEU fuel in the reactor can be protected to the level required until it is normally replaced with LEU. The targeted 31 facilities all have some degree of access to campus police, local law enforcement agencies, or other armed forces.

(c) A substantial number of the faclities will be required to refuel with LEU in the normal course of operations. In the case of TRIGA reactors, no HEU fuels are expected to be available. Further, presuming NRC's initiative is supported by other government agencies, DOE should not responsibly supply HEU fuels to their facilities or to benefactor universities.

(d) It has been demonstrated by past rulemaking efforts that affected licensees are willing to provide required levels of physical protection to protect against the theft or diversion of a significant quantity of SNM.

On the latter point, licensees are justifiably apprehensive of the NRC position on the 100 Rem/hr at 3 ft "self-protection" limit for each and every fuel element when dozens of fuel elements are required to form a formula quantity. To prevent a facility from being construed as Category I (full protection required) when a single in-core fuel element falls below the above radiation limit, we recommend that the Commission promptly move forward with the completion of the previously published 10 CFR 73.67(d) rulemaking which allows the 100 Rem/hr self protection criteria to be averaged over a significant quantity of HEU (a quantity of one kilogram has been suggested). It is noteworthy that some licensees have placed additional locking devices around and over the reactor cores and that the added physical protection measures have involved a few tens of thousands of dollars rather than the $1-2 million required to convert a low power reactor to LEU fuel.

Precept 3 is required to protect the licensee against exceptional costs associated with licensing. The minimum licensing fee is $41,300 which is waived for universities but not for industrial, non-power reactor owners. The SAR to support a license change is costly both for universities and industrial owners and is estimated to require a man-year level of effort. Further, the Commission should adopt a change in its rules so that licensees can utilize LEU fuels in lieu of HEU fuels subject to a satisfactory finding under 10 CFR 50.59 and a satisfactory finding by DOE or NRC (perhaps on a generic basis) that such use of LEU fuel will involve no adverse affects to the reactor, its environs, or the public. Every effort must be made by the Commission to assure that its actions in this rulemaking do not lead to intervenor actions, which can be very time consuming and expensive to the licensee. An estimate of the costs to implement the rule (without costs due to intervenors) is set forth in the Appendix.

Recognizing the sensitivity surrounding the utilization of HEU in the international non-power reactor community, GA Technologies has cooperated fully with the NRC, DOE, and other government agencies by developing a fully acceptable LEU fuel that not only replaces HEU TRIGA fuel but can be used in many instances as a replacement for HEU MTR plate-type fuel. We are so confident of the performance of this LEU fuel that we have discontinued the sale of any fuel enriched to greater than 20 percent in U-235 since 1979. End of life demonstration testing of this fuel is continuing under the DOE-sponsored RERTR Program.

We urge you and the other commissioners to consider the many details of the matter under consideration so that undesirable consequences can be forestalled.

Thank you for your consideration of this material.

Yours sincerely,

WLWhittemore

William L. Whittemore
Manager
TRIGA Reactors Facility

HMA:WLW:hc

Attachment:
Appendix A

APPENDIX: Costs to Implement HEU to LEU Core Conversion

It may be useful to point out that industrially owned non-power reactors (five in number) have costs associated with the proposed rule on LEU fuel, some of which are not normally borne by university reactor owners because of their DOE support. On the other hand, these costs are real for all non-power reactor owners and are part of the total costs for the proposed rule.

Item	Cost
i. Core replacement	$1-2M
ii. SAR to support license Amendment (~1 man year)	~100k
iii. License Amendment Fee	41.3k
iv. Shipping HEU core to disposal*	50-75k
v. Reprocessing cost for HEU core.*	≥525k
credit for residual HEU	200k-400k
Total costs	$1.72-2.75M
Credits	$0.200-0.4M

The average cost of about $2M per facility to implement the rule will result in a total cost for this program of about $64M for 31 facilities.

*GA Technologies had direct experience in 1982 with shipping several hundred spent TRIGA fuel elements to burial and/or processing.

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RHODE ISLAND ATOMIC ENERGY COMMISSION
Nuclear Science Center
South Ferry Road
Narragansett, R I 02882

June 20, 1984

The Honorable Nunzio J. Palladino,
Chairman
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Chairman Palladino:

The position of the National Organization of Test, Research and Training Reactors concerning the conversion of non power reactors from HEU to LEU fuel was first transmitted to you in a letter dated July 27, 1983 from Lincoln Clarke Jr.. More recently, TRTR has expressed its position (presented by Paul Turinsky, Chairman NEDHO) during the December 20, 1983 meeting of the Commission, before the ACRS Subcommittee on June 12, 1984, and through letters to you from M. Levenson dated March 19, 1984, John Lucey dated May 23, 1984 and J. M. Hendrie dated June 11, 1984.

In addition, TRTR participated in the recent ANS sponsored panel discussion which resulted in the transmittal to you of Dr. Zebroski's paper entitled "Relative Diversion Exposures of High Enriched Uranium: Relation to University Research Reactors".

TRTR remains opposed to the proposed LEU conversion rule and in addition is opposed to the proposed security upgrade rule which has recently surfaced to accompany the LEU conversion rule. As stated in the documents referenced above, TRTR believes that the proposed rules are unnecessary because they address threats which are already acceptably small and believes that the proposed rules will so overburden the non power reactor community that facility shutdowns will inevitably occur. Even if funding is provided by DOE for actual conversions, the staffs at non power facilities will be hard pressed to meet the paperwork and technical requirements of the proposed rules while fulfilling their existing economic and program obligations.

The National Organization of Test, Research and Training Reactors offers the resources of its membership to seek out alternatives to the proposed rules, if such alternatives are necessary.

Very truly yours,

A. Francis DiMeglio

A. Francis DiMeglio
Chairman, TRTR

841417

NORTH CAROLINA STATE UNIVERSITY | AT RALEIGH
SCHOOL OF ENGINEERING

DEPARTMENT OF NUCLEAR ENGINEERING
Box 5636 Zip 27650

June 21, 1984

RAYMOND L. MURRAY, Professor
Nuclear Engineering Department
North Carolina State University
P. O. Box 5636
Raleigh, North Carolina 27607

The Honorable Ronald Reagan
President of the United States
The White House
Washington, DC

Dear President Reagan,

I should like to express my concern about the possibility that the Nuclear Regulatory Commission may adopt a rule proposed by the State Department that university nuclear reactors must go to low enrichment fuel and increased security requirements.

As one of the team that built the first university reactor in the United States and established the first nuclear engineering education program, and as a faculty member in that discipline for over 30 years, I firmly believe that laboratory and research experience with a reactor is an essential part of learning for nuclear engineering students.

The proposed rule would increase the cost of maintaining a reactor at many schools to the point where they would have to shut down their facilities. This would weaken the education of some of our future nuclear leaders in an industry that is already beleaguered with difficulties.

Analysis of the rule indicates that the amount of uranium-235 involved does not pose a significant increased threat of proliferation.

The rule is being urged upon the NRC by the intervenors who were able recently to shut down the reactor at UCLA by protracted legal action. The university simply could not afford the cost of defense. I fear that the success of these anti-nuclear groups in closing university reactors will provide momentum for a more ambitious objective, that of stopping nuclear power.

Please consider the impact of this proposed rule on university education, the nuclear industry, and on our energy security, and use your influence to see that it is not adopted.

Thank you and best regards.

Respectfully,

Raymond L. Murray

Emeritus Professor
of Nuclear Engineering
North Carolina State University
Raleigh, NC 27695

NRC

OSU

The Ohio State University

Nuclear Reactor Laboratory
1298 Kinnear Road
Columbus, Ohio 43212
Phone 614 422-6755

June 22, 1984

The Honorable Nunzio J. Palladino
Chairman
United States Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Chairman Palladino:

I am writing concerning the proposed rule on conversion of non-power research reactors from the use of high enrichment uranium fuel to low enrichment uranium fuel. My concerns center on the potential costs of such a requirement on low-power, "lifetime core" reactors such as the Ohio State University Research Reactor (10 kw steady-state thermal power).

As you know, many universities face severe budgetery constraints. Support for many university-owned reactors, such as the OSURR, has been subject to major reductions in recent years. Any additional major costs which might result from the proposed HEU-LEU conversion could lead many universities to permanently shutdown their reactors. The proposed rule, coupled with associated intervenor action, makes this a real possibility in the case of the OSURR. I understand that this has already occurred at UCLA.

Costs for HEU-LEU conversion can be prohibitively high for many financially strapped universities. Even if funding for LEU fuel and staff time necessary for conversion activities were provided by the government (which, I understand, has been deleted for FY85 in the House), many universities could simply not afford prolonged litigation which might be forced by determined intervenors. The rulemaking process is unlikely to mitigate this possibility.

I believe that the Commission should give very serious consideration to the costs as well as the benefits of the proposed rule. Given the low diversion risk presented by university-owned research reactors, the very high potential costs in terms of loss of research and educational resources, as well as money, should be given the most serious consideration.

Thank you for your consideration of this issue. Please note that the views expressed herein are not an official policy statement of The Ohio State University as a whole, but do represent the overall concerns and views of the OSURR staff and Nuclear Engineering Program faculty.

Sincerely,

Joseph W. Talnagi Jr.

Joseph W. Talnagi, Jr.
Senior Research Associate
Nuclear Reactor Laboratory

JWT/vl

cc: D. W. Miller, OSU
P. J. Turinsky, NCSU (NEDHO)

College of Engineering

RECEIVED
84 JUN 2
OFFICE OF SEC'Y
ADMIN.

OSU

The Ohio State University

Nuclear Engineering Program
1133 Robinson Laboratory
206 West 18th Avenue
Columbus, Ohio 43210

Phone 614 422-8519

June 22, 1984

The Honorable Nunzio J. Palladino
Chairman, United States Nuclear Regulatory Commission
1717 H. Street
Washington, DC 20555

Dear Chairman Palladino:

Conversion of Fuel Elements of Non-Power Reactors
from Highly-Enriched to Low-Enriched Uranium

I am writing to express my concern regarding an imminent decision the Commission will be making regarding HEU fuel in research reactors. My concern relates to the perceived reduction this conversion will make in the risk of nuclear energy. In my opinion, the opposite will occur if we are unable to continue operation of university research reactors. This is a consequence of the minimal risk posed by the operation of these reactors, plus the contribution they are currently making to education of nuclear engineers, the training of nuclear power plant operators, and the development of improved technology, all areas important to the safe operation of nuclear power plants.

In summary, I strongly encourage you to consider carefully the impact of your vote with regard to conversion of research reactors from HEU to LEU fuel. The continued operation of university research reactors is important to the future of nuclear energy. If they are required to convert, their continued operation can be assured only if there is adequate funding available for both the technical and the legal effort which certainly will be required.

I thank you for your consideration of my opinion. I would be pleased to have an opportunity to speak with you personally regarding this issue.

Sincerely,

Don W. Miller
Professor and Chairman

DWM:lam
cc: Dr. George A. Keyworth, White House Presidential Science Advisor
Mr. Jack Zerbe, NRC Office of Policy Evaluation
Dr. Edward H. Jennings, President
Dr. Jack M. Hollander, Vice President for Research and Graduate Studies
Dr. Donald D. Glower, Dean, College of Engineering
Dr. Robert F. Redmond, Associate Dean for Research, College of Engineering

OSU

The Ohio State University

Nuclear Reactor Laboratory
1298 Kinnear Road
Columbus, Ohio 43212
Phone 614 422-6755

June 25,1984

The Honorable Nunzio Palladino
Chairman, USNRC
Washington, D.C. 20555

Dear Chairman Palladino,

As a part of The Ohio State University, the Nuclear Reactor Laboratory (NRL) should participate in teaching, research, and public service activities. A review of our utilization for over twenty years will verify that this has been and is being done. Our teaching efforts supply qualified engineers from Ohio State University (and the University of Cincinnati through the D.O.E. Reactor Sharing Program),trained technicians from Terra Technical College (also through the Reactor Sharing Program), and skilled Reactor Operators for the nuclear power industry from Research Reactor Training programs (similar to those required by NRC Generic Letter 84-10). Research efforts on nuclear instrumentation are providing the industry and the NRC with better detection capabilities. Current research at the NRL involves neutron sensor projects with Westinghouse, Reuter Stokes, and the NRC. Part of our service to the public is to provide information on our research capabilities, particularly in the area of neutron activation analysis. This is routinely done for local high schools. The success of these efforts is reflected in the success of local science fair participants who have utilized the facilities of the NRL. One such student advanced to the International Science Fair in May, 1984.

It appears that passage and implementation of the HEU to LEU conversion rule will put in jeopardy the activities of The Ohio State University Nuclear Reactor Laboratory. As described above, some of these activities are simply supported by the NRC while others are required. If the ultimate goal of HEU to LEU conversion is to make the nuclear community safer, then in the long run this conversion will backfire. Certainly many research reactors will close due to financial and/or relicensing problems created by conversion. The result will be fewer well trained engineers, technecians, and reactor operators; less reliable nuclear instrumentation; and a less well informed public. The risk to the nuclear community and ultimately the general public if this happens must certainly be greater than the existing diversion risk for HEU.

Sincerely,

Richard D. Myser

Richard D. Myser
Associate Director

UNIVERSITY OF MISSOURI

Research Reactor Facility

Research Park
Columbia, Missouri 65211
Telephone (314) 882-4211

June 29, 1984

Nunzio J. Palladino
U.S. Nuclear Regulartory Commission
Office of the Secretary
Washington, DC 20555

Dear Commissioner Palladino:

I understand that the NRC is now making a final decision about the rule that research reactors which are licensed by NRC should convert from HEU to LEU. In the past, we have expressed our position on this matter but let me reiterate several of my concerns. First, neither the present capablilities nor the future technically achievable capability of these reactors should be compromised. The health and safety of the nation is better served by having these reactors operating than shutdown. Second, reactors such as MuRR which would be degraded in capability by conversion should be given an exemption. The research objectives of these reactors can only be met with present capabilities. In addition we can only meet the challenge of the competition from abroad by upgrading these reactors. Third, the full cost of conversion should be born by the Federal Government since this is a change in a policy by the State Department and is not a change in any real threat caused by these facilities.

We have an added concern that security standards are being ratcheted in conjunction with the HEU-LEU ruling. The present security required by NRC for a facility such as ours is adequate to meet the postulated threats. Our present security plan is new having been approved by NRC within the last year. No ratcheting of security requirements should accompany a conversion from HEU to LEU or with an exemption to such a conversion. I am convinced that a valid cost benefit analysis would more than substantiate the present level of security at a facility like ours.

If we can be of any additional help in your deliberations please call on us.

Sincerely,

Robert M. Brugger
Director

B/ctb

COLUMBIA KANSAS CITY ROLLA ST. LOUIS
an equal opportunity institution

UNIVERSITY OF MISSOURI-COLUMBIA

College of Engineering

Office of the Dean
1010 Engineering Building
Columbia, Missouri 65211
Telephone (314) 882-4375

July 6, 1984

Mr. Nunzio J. Palladino
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Joe:

It has come to my attention that the NRC Commissioners are considering issuing proposed rules which would require research reactors licensed by NRC to convert from high-enriched uranium (HEU) to low-enriched uranium (LEU). I am deeply concerned about the impact this decision will have on university teaching reactors such as the one we operate [illegible] the University of Missouri-Columbia.

[illegible] my opinion, this decision would cause many university reactors to permanently shut down because of both licensing and financial concerns. [illegible] universities simply cannot afford lengthy and costly licensing processes financially or in terms of staff. Some nuclear engineering departments are under pressure from university administrators because of declining enrollments and high costs per credit hours. If this ruling is adopted, it may be enough to force university administrators to close down reactors and academic programs. The real cost will be the loss of educational experience for our future nuclear leaders and the research associated with university reactors. The health and safety of our nation is best served by having these reactors in operation.

It is my understanding that these augmented security requirements are being pushed toward implementation in spite of NRC staff's position that current security requirements are adequate. I urge a more careful evaluation before implementing these security requirements.

Sincerely,

WRKimel

W. R. Kimel
Dean

/pk

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NRC FORM 318 (10-80) NRCM 0240

DOCKET NUMBER
PROPOSED RULE PR-50 (1)
(49FR 27769)

WASHINGTON STATE UNIVERSITY
PULLMAN, WASHINGTON 99164

NUCLEAR RADIATION CENTER

July 25, 1984

'84 JUL 30 P3:48

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Docketing and Service Branch

Gentlemen:

The manner in which the proposed HEU/LEU rule was passed and published in the federal register on July 6, 1984 (Vol. 49, No. 13) disturbs me very much. First and foremost, the rule was published exactly as it was originally drafted by the commission without regard to the formal comments made by the ANS, EPRI, ACRS, NEDHO, TRTR, G.A. Technologies and Union Carbide. Secondly, the rule was published during the worst of all possible times for the facilities impacted with only a 60 day comment period. University reactor facilities, which comprise the majority of the facilities impacted by the rule, have a reduced staff during the summer time due to the nature of academic institutions. This greatly impairs the impacted facility's ability to comment on the proposed rule.

The WSU reactor facility, which is one of the facilities impacted by the rule, did not receive a copy of the rule until 7/23/84. Thus, over 28% of the comment period had elapsed before WSU was officially notified of the proposed HEU/LEU rule.

I believe that the 60 day comment period for the proposed HEU/LEU rule is capricious and unreasonable for the above-stated reasons. I herewith request an extension of the comment period for another 60 days.

Sincerely,

W. E. Wilson

W.E. Wilson
Associate Director

WEW:mt

Acknowledged by card 7/31/84
pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

Radiation Center
Oregon State University
Corvallis, Oregon 97331 503 754-2341

July 26, 1984

'84 JUL 30 P2:26

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Docketing and Service Branch

Gentlemen:

Oregon State University respectfully requests a 60-day extension of the September 4, 1984 closing date for comments on the Commission's proposed rule entitled, "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors," as published in the Federal Register, Volume 49, No. 131, July 6, 1984, pages 27769 through 27772.

In support of this request we submit the following information for your consideration.

a. We feel that this rulemaking addresses a very serious issue of vital importance, and are convinced that many of the nonpower reactor licensees, especially the affected academic research reactors, need more time to prepare their comments on this NRC proposal. While the Federal Register publication date would make it appear that adequate time for commenting has been provided, as you recognize, most of the academic community do not have the resources to continually monitor Federal Register entries. Newsletters and regulatory subscription services provide a great deal of help regarding proposed regulatory changes, but in general, the Commission has provided copies of specific proposed rulemakings to the nonpower reactor licensees, when they are to be involved. In the current rulemaking, however, the Commission's distribution of their proposal was received at OSU on July 26, 1984, which represents an initial loss of about 35% of the working days in the stated comment period. In addition, most academic programs are faced with reductions in manpower during the July-August time interval due to staff vacations and the absence of key faculty during the summer.

b. The annual meeting of the National Organization of Test, Research, and Training Reactors (TRTR) is scheduled for August 23 and 24, 1984. Needless to say, there will be much discussion of this Commission proposal during that meeting, and the opportunity for

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the nonpower reactor community and the Commission to exchange information on this issue will be quite important. Since many licensees will most certainly gain new information regarding the proposed rule as a result of the TRTR meeting, it would appear to be valuable to the Commission and to the licensee community if more time were allowed after the meeting for the preparation of comments. With the present scheduled comment period, there will be only one week for the preparation and submission of comments after the meeting.

c. From the standpoint of Oregon State University specifically, the comment period makes it very difficult for us to devote the time we feel is needed to prepare our comments, due to prior commitments to the NRC and to the absence of personnel resulting from normal staff vacations which were previously scheduled. In particular, we are presently working very hard to meet a Commission deadline of September 14, 1984 for the implementation of our completely new emergency response plan, we are working on our annual report which has a Technical Specifications submittal date of September 15, 1984, and we are contributing to a Commission peer review study of a model for meeting a currently effective regulatory criterion dealing with physical security.

In view of the preceding considerations, we would greatly appreciate your favorable reaction to our requested extension, and sincerely believe that such an action would have a positive impact on this proposed regulatory action. Please let me know if we can provide additional information on this matter.

Yours sincerely,

C. H. Wang
Reactor Administrator
Director, Radiation Center

CHW:jrl
cc: USNRC, Deputy Executive Director for Operations, Washington, D.C. 20555 (Attn. Mr. Victor Stello)
USNRC, Standardization & Special Projects Branch, Division of Licensing, Washington, D. C. 20555 (Attn. Mr. Robert Carter)
USNRC, Documents Management Desk, Washington, D. C. 20555
USNRC, Region V, Walnut Creek, California (Attn. Regional Administrator)
Director, Oregon Dept. of Energy, Salem
Mr. Wade Richards, Chairman, ANS-15 Standards Committee
Dr. T. D. Parsons, Vice President for Administration
Prof. S. Binney
Prof. B. Dodd
Prof. A. Johnson
Mr. T. Anderson

DOCKET NUMBER
PROPOSED RULE PR-50
(49FR27769)

Committee Correspondence
STANDARDS COMMITTEE

Reply to: W. J. Richards
Argonne National Lab
P. O. Box 2528
Idaho Falls, ID
83403-2528

27 July 1984

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Attention: Docketing & Service Branch
Washington, D. C. 20555

Dear Sir:

The Proposed Rule concerning limiting the use of Highly Enriched Uranium in Domestic Research and Test Reactors arrived here on July 25, 1984. I noticed that the deadline for comments is September 4, 1984.

This proposed rule will have significant effects on all U. S. research and test reactors. It arrives at a time when most university reactor administrators are not present (absent for summer break) or reactor staffs are at minimum strength. Also, the annual Training Research and Test Reactor (TRTR) meeting will be held during the time period from August 22-24, 1984.

Since this proposed rule will have such an impact and the input from the research reactor community is very important, I respectfully request you consider extending the comment period for at least 30 days. This will allow the community to make sure everyone is aware of the proposed rule and also to have discussion concerning the rule at the upcoming TRTR meeting.

Sincerely,

Wade J. Richards
W. J. Richards, Chairman
ANS-15 Standards Committee

WJR:kk

cc: ANS-15 Membership
B. Carter
V. Stello

Acknowledged by card 8/3/84
pa

1616

DOCKET NUMBER
PROPOSED RULE PR-50 ②
(49 FR 27769)

'84 JUL 31 P2:33

DEAR SEC. of the Commission 7.29.84.
MY COMMENT ON THE USE OF LOW ENRICHED URANIUM IN RESEARCH REACTORS IS MIXED

1. I AGREE THE USE OF HEU IS RESEARCH REACTORS IS UNNECESSARY + DANGEROUS.
2. I DISAGREE THAT SUDDENLY SWITCHING TO LEU WILL NECESSARILY REDUCE DANGER.
3. THE SUDDEN SURPLUS OF HEU FROM RESEARCH REACTORS WILL PRODUCE A GLUT ON THE MARKET OF BOMB MAKING MATERIAL WHICH WILL TEMPT ORGANIZED CRIME + DANGEROUS FORIEGN GOVTS.

Marvin I Lewis

M. I. LE
6504 BRADFORD TERR.
PHILA., PA. 19149

M. I. LEWIS
6504 BRADFORD TERR.
PHILA., PA. 19149

PHILADELPHIA

Domestic Rate

Sec. of the Commission
USNRC
Washington DC 20555

Attn: Docketing & Service.

Acknowledged by card 8/3/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49FR 27769)

③

LESLIE C. WILBUR
PROFESSOR OF MECHANICAL ENGINEERING
DIRECTOR, NUCLEAR REACTOR FACILITY
Worcester Polytechnic Institute
Worcester, Massachusetts 01609

Registered Professional Engineer
Commonwealth of Massachusetts
PE 8196

Business 617-793-5688
Residence 617-838-2553

July 31, 1984

-2 A11:23

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Re: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

Dear Sir:

I am opposed to the proposed rule as published July 6, 1984 in the Federal Register for the following reasons:

1. The rule will cost U. S. tax payers millions of dollars, and, in my opinion, will be a waste of money. Security measures at research and test reactors are either adequate to safeguard the used fuel on hand or can be readily made adequate. For those reactors requiring fresh fuel periodically, shipment timing and storage access can be tailored to the individual situations to give reasonable assurance that the fuel is adequately safeguarded.

   The rule statement that "The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use." is a reflection of the nuclear policies promulgated by President Carter. Those policies failed to accomplish anything except accelerate the demise of nuclear power in the United States and reduce our international leadership credibility. American voters rejected President Carter decisively, and it is ironic that holdover appointees are still implementing government restrictions based on the Carter philosophy.

2. There is no firm commitment for funding the proposed expensive fuel changes. In the case of "lifetime fuel" reactors, the entire cost of the conversion is chargeable to the new rule. Given the cost of maintaining a nuclear program and presently reduced student support, university administrators are hard pressed to justify the cost of their nuclear reactors. Any added burden, especially one conceived to be politically inspired, will help to confirm the perception that regulatory costs for a university nuclear reactor are simply too burdensome, and may well lead to decommissioning reactors. My own administration is concerned that the trend is in the direction of ever increasing cost of both operation and decommissioning. My opinion is that any substantial cost associated with the proposed rule may trigger decommissioning of our reactor. Although our program is small, we have fed graduate schools and industry competent nuclear-oriented engineers for nearly twenty five years, and our graduates hold responsible positions in diverse segments of the industry. I believe we contribute significantly to nuclear safety and that closing down our

Acknowledged by card 8/3/84 DL

reactor and other similar programs would result in lessened U.S. competence in the building and operating of nuclear reactors. Parenthetically I would like to point out that as I am very nearly at retirement age these comments are not based on any desire on my part to preserve my position or maintain the status quo for my own benefit. I will be retired before the rule can be implemented.

3. If the rule is passed and funding proves to be adequate, there are still difficulties. Information on the availability of acceptable new fuel and shipping casks must be obtained before a meaningful plan can be developed and submitted to the NRC detailing a proposed schedule. It will be important to minimize outage time, which means dovetailing fuel removal and acquisition. If fuel is obtained ahead of old fuel removal, it must be stored outside the reactor at facilities which do not presently need or have new fuel storage vaults. Even though the new fuel is of low enrichment, its diversion could have major propaganda implications.

   Reactor facilities should not be expected to provide timetables in the absence of firm specific data on fuel, casks and funding.

Very truly yours,

L. C. Wilbur

L. C. Wilbur, Professor of
Mechanical Engineering
and Director,
Nuclear Reactor Facility

LCW:ama

23

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) ④

IOWA STATE
UNIVERSITY

Department of Nuclear Engineering
261 Sweeney Hall
Ames, Iowa 50011

Telephone 515-294-5840

July 31, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Docketing and Service Branch

Dear Sir:

This letter covers comments on the proposed amendment to regulations in 10 CFR Part 50, concerning "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors." This proposed amendment (rule) concerns my Department directly, as we are the operators of a 10 kW (thermal) UTR-10 research reactor which would be affected by the actions required by the rule.

I must note that the copy of the proposed rule from which I am working came to me second hand, by copy from Dr. Paul J. Turinsky, Chairman of the Nuclear Engineering Department Heads Organization. The failure of the Commission to bring this matter directly to the attention of those affected by it represents a most serious breach of the spirit of due process, and has prompted me to include in my comments a procedural section. My conclusion is that the Commission should withdraw the rule for redrafting, which redrafting would be appropriate only after it has solicited and, to the extent possible, obtained input from all the affected parties.

Very truly yours,

B I Spinrad

B. I. Spinrad
Professor and Chair
Department of Nuclear Engineering

BIS:db
Enclosure

cc: R. A. Hendrickson
D. R. Boylan
D. J. Zaffarano

Acknowledged by card 8/6/84 pd

Comments on proposed rule, amending regulation of the U.S. Nuclear Regulatory Commission in 10 CFR Part 50, with regard to "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors."

B. I. Spinrad Chair
Dept. of Nuclear Engineering
Iowa State University
Ames, Iowa

Qualification

Our Department has been operating a UTR-10 Research Reactor for 25 years. It is fueled with uranium-aluminum alloy in individual plates that can be assembled into fuel assemblies and placed into a two-slab water region within what is effectively a block of graphite. The uranium is currently HEU. The amount of HEU in our possession is about 4.6 kg, including about 100 g in the form of detector foils, fission chambers, etc. Our reactor would therefore be directly affected by the proposed rule.

Background

The Iowa State University UTR-10 has been used primarily as a teaching tool. Over the years, we have awarded over 400 degrees in Nuclear Engineering. Over 90% of our graduated students have received part of their training at the UTR-10. (Those who did not were early graduates from the time before the reactor was installed).

During the year 1983-1984, typical of recent years, the reactor was operated for 322 hours and produced 122 kilowatt-hours of energy. Teaching was responsible for 61% of the time and 82% of the energy use; maintenance and operator training took 24% of the time and 14% of the energy use; and research occupied 15% of the time and .5% of the energy use. Although the reactor is rated at 10kW, power above 1kW is rarely required: during operating periods, the average power was just under 380 watts.

Although the reactor is only used to a small extent for research, it is a vital tool to our faculty and graduate research program. It is used by two faculty members at quite low power in a major program, sponsored by the National Science Foundation, to investigate the neutron "noise" generated by moving reactor core components. It is also used in sponsored research programs dealing with neutron activation analysis of high cross-section materials and with sensing small concentrations of radioactive gases.

During the entire period of operation, the fuel for the reactor has been well guarded, being either locked into the reactor or off-loaded into secure facilities. There has never been a real challenge to our physical protection system--only simulated challenges during exercises of that system. Our total protection system has been approved and checked by the (U. S. Nuclear Regulatory) Commission.

Need for the Rule

It is recognized that major quantities of highly enriched uranium in research reactors could, in principle, be diverted and refabricated into nuclear weapons. Protecting against this contingency is presumably the major reason for the proposed rule.

The simplicity of the protection and accounting process in a reactor such as ours makes both the probability of diversion extremely low, and the chance of diversion being undetected virtually zero. In order to have a reasonable chance of making a fission weapon, a divertor would probably need at least two complete reactors worth of fuel. This would have to be accomplished by two separate thefts, and the further processing of the material would have to be clandestine. Such clandestine processing would itself be very hard to pull off, both because of the need for avoiding police manhunts, and because the radioactivity of the material provides an important tool for police to use in recovering such material.

One therefore concludes that the main risk involved with HEU research reactor fuel comes from larger reactors that maintain large stocks of both fresh and spent fuel, and that the benefits to the public in extending further safeguards to limited-quantity facilities such as ours are extremely small.

This matter has been thoroughly examined by Zebroski (E. L. Zebroski, "Relative Diversion Exposures of High Enrichment Uranium: Relation to University Research Reactors"; presented at the American Nuclear Society meeting in New Orleans on June 4, 1984). His summary and conclusions are appended to these comments.

Based on these observations, I recommend that the rule be amended to exclude facilities possessing less than 5 kg of HEU from the requirements that are listed. This exclusion would permit the Commission's activity to be focused more strongly on those facilities that represent higher categories of societal risk.

Technical Implications of the Rule on our Operations

If <20% enriched fuel of proper specifications were available, we see no difficulty in operating our reactor with it. By "proper specifications", we mean that substitute MEU (medium enrichment fuel, less than 20% enriched in 235U) fuel should also be in plate form of the same dimensions as the present fuel, should have approximately equal reactivity worth per plate, and should not qualitatively alter the reactivity coefficients of our reactor.

Our education and training uses of the reactor would be essentially unchanged. Our research uses might require operation at 10-20% higher power than at present, but our operations are so far below rated and licensed power that this is not a significant matter.

Technical Operations Involved with Changing Fuel, and Their Costs

Changing fuel according to this rule would not be a difficult matter for us provided that appropriate shipping containers for our present fuel were available, and that the U.S. Department of Energy was willing to take possession of these containers when loaded.

If the fuel changeover were to be done all at one time, we would have to make special security arrangements, however. For some period, the amount of fuel in our possession would be doubled. We would have to prepare temporary arrangements, get them approved, and cope with this contingency. Therefore, our preferred modus operandi would be to schedule the changeover gradually--over a period of several years--so that the amount of fuel in our possession never exceeded our present storage capability. Under these circumstances, we could change one or two fuel assemblies at a time, storing the replaced assembly and delivering it for shipment as the container became available. The shifting of fuel in this mode is within our present operational capability. An additional bonus of this mode is that at each step the operational characteristics of the reactor would change by only a small amount, which would be quite well established from previous experiences so that any required amendments to the operating procedures would be based on firm, site-specific data.

We are concerned about the costs of procuring the new fuel and shipping it. We have a very low-budget operation, in which costs for personnel and maintenance are borne by our academic budget. We pay insurance costs of about $2000/year out of our academic "current expense" allocation, and expend about an equal amount on small parts and shop costs. Our fuel material is a lifetime supply as we do not burn up a significant amount, even over decades. It is of very simple design, but we are aware that fabricating even such simple fuel has become very costly. Moreover, at a price of about \$30/g of contained ^{235}U, 5 kg of ^{235}U is worth \$150,000. Our present fuel is on loan from DOE, and we hope that the MEU fuel would be similarly supplied. If we had to purchase it, we could not afford it.

We have not priced the cost of shipping fuel, but we understand that this, too, is an expensive operation, which we could not afford under our present circumstances.

Safety Implications of the Changeover

We do not, ourselves, see any significant changes in the safety of our operation resulting from the changeover.

Problems Foreseen

The question of costs has already been mentioned. If we had to pay any of the external costs of the changeover--i.e., fuel procurement, spent fuel shipping--our financial resources for remaining in operation would be jeopardized.

Equally bothersome is the possibility that antinuclear groups might force a reopening of the operating licensing procedure. Such groups have been granted status both by licensing boards and by judicial bodies. They are very well financed, and have been on some occasions far more capable of bearing the costs of protracted litigation than universities have been. Although we are convinced that our reactor is provably safe to operate, we can not afford to carry out litigation against determined opponents.

Conclusions

1. A change from HEU fuel to MEU fuel in very low power research reactors is of trivial value in safeguarding against nuclear weapons material diversion for weapons purposes.
2. Such a change is technically feasible and does not materially affect operational safety.
3. Such a change is costly, on the scale of budgets available to low power research reactor operators.

4. Such a change has potential to trigger litigation by antinuclear groups.
5. Such litigation can only be avoided by the Commission's undertaking generic rule-making in advance of mandating the change.

Recommendations

1. As already stated, we recommend that reactors with less than 5 kg of HEU on site be exempted from mandatory changeover to MEU.
2. If this recommendation is not accepted, the following recommendations are substituted:
    - 2a. We recommend that the rule clearly specify that its application to small reactors shall be contingent on the availablity of government financing for procuring the new fuel and shipping the old.
    - 2b. We recommend that the NRC undertake a generic rule-making procedure on the question of safety of small reactors when MEU is substituted for HEU; and that any changeover be contingent on a finding that this changeover does not significantly affect safe operations.

Procedure

The Commission, in drafting the proposed rule, appears to have sought input from various interested associations. These include groups who have been known to be controversially activist with regard to the hazards of even small quantities of HEU, as well as testimony from groups within the nuclear community.

I am nevertheless resentful that such affected groups as ours at Iowa State were not specifically invited to comment. On other occasions, that has been the case.

These matters make the rule flawed. I am not a lawyer, and do not know whether these flaws are legally actionable. However, they taint the rule morally, and suggest that the whole rule-making process is one-step ahead of schedule.

To be ethically valid, the following steps are recommended:

1. Redraft the rule on the basis of comments received up to Sept. 4.
2. Resubmit this to the Commission.
3. Republish, if reapproved by the Commission, with a new comment and review period.
4. Complete and activate.

RELATIVE DIVERSION EXPOSURES OF HIGH ENRICHMENT URANIUM: RELATION TO UNIVERSITY RESEARCH REACTORS

Edwin L. Zebroski

Summary and Conclusions

The future conversion of overseas reactors with U.S.-supplied fuel to Low Enrichment Uranium (LEU) can be useful to reduce the possibility of diversion of significant amounts of strategic material. Future conversion, however, does not materially affect the existing residual risks associated with nearly 20 tons of High Enrichment Uranium (HEU) already exported. The characteristics of U.S. university research reactors appear to be in the lowest level of four categories of diversion risks. Five types of potential security questions are identified, including possible diversion or theft of material, although the quantities involved are insufficient to make nuclear explosives. Conversion of university reactors to low enrichment does not address four of the five issues.

The administrative processes involved in conversion to LEU as soon as technically practical appear nearly certain to lead to decommissioning some research reactors, with adverse impacts on U.S. capabilities for training, education, and research.

Simple administrative changes involving better communications appear likely to have a larger and much more timely effect in reducing residual risks involving public and local safety than all or most of the measures so far discussed, including conversion.

More thorough and systematic evaluation of the options which affect security appears prudent. The relative risks, benefits, and social impacts of changes in small domestic research reactors also would benefit from thorough study. Such thorough evaluations, beyond those so far evident, also appear to be consistent with policy statements published by the Nuclear Regulatory Commission for its own activities.

24

DOCKET NUMBER PROPOSED RULE PR-50 ⑦
(49 FR 27769)

MEMO from DEBORAH A. COHEN, M.D.

DOCKETED
USNRC

'84 AGO 10 P12:31

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

8/5/84

Dear Mr Secretary:

I am writing to tell you of my support of the new rule to require research reactors to switch from highly enriched to low-enriched fuel. This should be implemented as soon as possible. Any steps such as this ~~taken~~ will reduce the all-too dangerous situation of the proliferation and potential use of weapons-grade uranium.

Keep me informed of your decisions.

Thanks.

Sincerely,

Form 88-100 The Drawing Board, Inc. Box 505, Dallas, Texas

DEBORAH A. COHEN, M.D.
1847 NORTH KINGSLEY DRIVE
LOS ANGELES, CALIFORNIA 90027

Acknowledged by card 8/13/84 pl

25

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) ⑤

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

Rhode Island Atomic Energy Commission
NUCLEAR SCIENCE CENTER
South Ferry Road
Narragansett, R.I. 02882-1197

DOCKETED
USNRC

'84 AGO -8 A10:54

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

August 6, 1984

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Gentlemen:

This letter is transmitted on behalf of the National Organization of Test, Research and Training Reactors (TRTR) in response to the publication in the federal register on July 6, 1984 (Vol. 49, No. 131, pp. 27769-27772) of the proposed rule "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors". As stated in the proposed rule, the comment period is set from publication date to September 4, 1984. TRTR will comment on the proposed rule.

While recognizing the importance placed on this issue by the Nuclear Regulatory Commission, TRTR hereby requests that the comment period be extended by sixty (60) days to November 4, 1984. This extension is requested for two reasons: (1) the comment period coincides with a school recess time period when most members of the non power reactor community (the university group) are fully occupied with long standing commitments to research and travel made without knowledge of when and if the proposed rule would be published, and, (2) the TRTR membership is meeting at McMaster University on August 23 and 24, 1984. At this meeting presentations on the proposed rule will be made by the Nuclear Regulatory Commission staff and others. In addition, at the meeting TRTR plans a discussion amongst its membership concerning the proposed rule. These presentations and discussions will obviously provide considerable insight into the proposed rule and therefore form the basis for more enlightened comments from the affected community. The time period between the conclusion of the TRTR meeting and September 4, 1984 is not adequate to prepare and transmit comments to the Nuclear Regulatory Commission.

TRTR is appreciative of this consideration.

Very truly yours,

A. Francis DiMeglio

A. Francis DiMeglio
Chairman, TRTR

Acknowledged by card 8/8/84 pdc

AFD:cd

26

Aug 6, 1984

Alliance for Survival

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555
Att: Docketing & Service Branch

DOCKETED
USNRC

'84 AGO -9 A11:32

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

DOCKET NUMBER
PROPOSED RULE PR-50
(49FR 27769) ⑥

Dear Friends,

We support the proposed rule which would require approximately 30 nuclear reactors (research) to convert from highly enriched uranium fuel to low enriched fuel.

The conversions should be implemented A.S.A.P.! No reactors should be exempted from this positive rule. This is a beneficial step for our national security and we thank you for proposing it.

Sincerely,
Jerry Rubin
Coordinator - S.M./Venice Alliance for Survival

Acknowledged by card 8/10/84 pd.

27

DOCKET NUMBER
PROPOSED RULE PR-50 (9)
(49 FR 27769)

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DATE August 7, 1984
IN REPLY REFER TO P-8-84-347
MAIL STOP H805
TELEPHONE (505) 667-6069

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Attention: Docketing and Service Branch
Washington, DC 20555

'84 AUG 17 P12:20

Dear Sir:

The Federal Register, Vol. 49, No. 131, presents a proposed rule "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors" and asks for comments. As director of the University of Missouri Research Reactor (MURR), I have commented on this subject in the past. I would like to comment again based on experience at MURR.

I believe that it provides greater protection to the health and safety of the USA to have the MURR operate conducting research and training than to have it shut down, compromised, or held to its present administrative limits. For example, at MURR the studies of the effects of trace amounts of Se on the health of humans and animals are providing significant new understanding about the toxicity of Se. These sensitive measurements of Se could not and were not being made at reactors of lesser capability. Another example is the development by University of Missouri scientists of a radioactive agent to radiate bone cancer which is a significant advance in cancer therapy. The availability of the capabilities of the MURR stimulated this development. A third example is our measurement of the crystal structure of the new NdFeB compound to be used for hard magnets. These measurements helped to establish the patent position of a domestic company and helps to retain the nation's technical position compared to the challenge from the Japanese. Such a measurement was not tried at any other neutron source in the USA. The training provided to students related to these and the many other research projects at MURR is providing the kind of forward looking training that is needed to produce productive scientists and engineers. Such scientific advances cannot be continued if the MURR is compromised or shut down.

The LEU exercise has already compromised the research and training programs at MURR. For example, the time I am spending on writing these comments is time and effort not devoted to research. The LEU exercise has been going on for about five years and has taken time and effort of our staff to consider the consequences of lowering the enrichment, to prepare statements, and to present the arguments to the NRC and other agencies. This time and effort must be diverted from the true function of the MURR. Thus teaching and research have been compromised. So far, no compensation from the government has been forthcoming for this effort. The LEU exercise has already cost a lot.

Acknowledged by card. 8/21/84 pd

From the viewpoint of the MURR the government has put millions of dollars per year into the RERTR program since it started to develop LEU fuel for the effected reactors. This effort, in spite of the liberal funding, has been only partially successful. Only modest, real, new technological developments have come out of this effort and none so far that will improve the performance or cost effectiveness of the MURR. We are having to make these improvements on our own initiative with limited support from DOE. It is discouraging when we see these millions of dollars per year put into the RERTR program while the federal government provides limited support to the research at MURR. In the last few years, the government has put more per year into the LEU exercise than the government has put into support the true research and training at all the effected research reactors. This money that has been spent on LEU could have been better spent on developing a long lived HEU fuel element and supporting research.

From our viewpoint, the LEU exercise has provided a poor environment in which to train students. Consciously or unconsciously, the students receive the message that in the nuclear field one spends one's time on trying to overcome or ameliorate rules that curtail progress rather than spending one's time on trying to understand and solve technical problems and introduce real improvements. At MURR we are having to work hard to overcome this attitude and to keep the students focused on technical training and advancement. Such exercises as the LEU exercise also sap the morale and initiative of the staff.

From its beginning the LEU exercise has been based on a poor premise, namely that LEU should be developed so that the present capability of the effected reactors could be maintained. Science and engineering are based on progress, not stagnation. If the LEU exercise had to be conducted at all, it should have been based on the premise that LEU will be introduced and required only if it can be shown that no maximum or future technical capability of any reactor will be compromised. At MURR, we as scientists and engineers believe that we should push the performance of the reactor to its safe technical limit. We are working to upgrade the MURR from its present 10 MW to 21 MW power level. This upgrade is needed and provides excellent training for students. For example, we are designing a source to produce a beam of neutrons with energies between 1 eV and 30 keV. This beam should have few fast neutrons and gamma rays and should have a flux at the irradiation position of 10^{10} n/cm^2 sec. The beam will be used for boron neutron capture therapy, a technique of brain cancer therapy recently revived by the Japanese. It will tax our ingenuity of design to achieve this flux level. We will need the 21 MW to provide for treatment in a reasonable time.

At MURR we have one additional concern. While the Federal Register statement states, "licensed, non-power research reactors using HEU fuel are operated without undue risk to the health and safety of the public," we are concerned that implementation of the LEU rule will produce a ratcheting of security rules and regulations which will further compromise the performance of our research reactor. I recommend that the rule state that this rule and/or any exemptions from the conversion to LEU may not be used as a reason or excuse to add additional security requirements.

Sincerely,

Robert M Brugger

Robert M. Brugger
Director
University of Missouri Research Reactor

RMB:ks

Cy: Congressman Harold Volkmer
George Keyworth, Science Advisor to the President
CRM-4 (2), MS A150
P-8 File

DOCKET NUMBER PR-50 (11)
PROPOSED RULE (49 FR 27769)

201 East Hyde Street
Tucson, Arizona 85704
August 8, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555
Attention: Docketing and Service Branch

84 AUG 17 P12:31

I am writing to comment on the proposed rule published in the Federal Register(Volume 49, No. 131, page 27769) regarding limiting the use of uranium enriched to greater than 20 percent U-235 in domestic non-power reactors.

The background of this rule indicates that the initiative to reduce the enrichment of uranium in domestic non-power reactors originates from "a policy to encourage conversion by foreign operators." However, the only limitation of enrichment in US reactors indicated is for 31 US non-power reactors (25 owned by universities, five by private businesses, and one by the government). Most,if not all, of the foreign reactors which use uranium enriched to greater than 20 percent U-235 are financed and operated in their countries in the same category as US reactors at national laboratories. It should be determined whether a significant number of foreign reactor operators might potentially be influenced toward conversion by a plan to limit enrichment of US university-owned and privately-owned reactors, without a similar program for all other US non-power reactors. (I am not encouraging such limitation on the reactors at the US national laboratories -- they are essential to this nation and should not be hamstrung by such a limitation -- but the policy may be of no use except in limitation of enrichment of foreign reactors which do not exist.)

Since the conversion plan was initiated by the commission for international policy purposes, and since the affected reactors are currently operated under existing licenses without undue risk to the health and safety of the public, it is proper that the commission should bear the costs of conversion, including the costs of development of new fuels, certification and testing, purchase and delivery of new fuel and disposal of the present fuel, as well as waiving licensing fees. In addition, the commission should cover all of the costs of conversion, which would include development of procedures for conversion and for transportation of the new and old fuel, and new procedures which must be written to use the new fuel, as well as legal fees and the cost of travel to hearings and other meetings in connection with the conversion. The organizations which will need to undergo conversion under this rule are currently operating their reactors safely with adequate staffing. The new burden to the staff and the cost of attorney's fees will be more than some of the organizations can bear, and all of them will need to put resources in areas not anticipated in the current license agreements with the commission. It should be noted that few, if any, benefits, will come to the operators from this program, but many disadvantages, such as the need to shutdown for conversion, reduced core flux and neutron spectrum change, more frequent refueling, and more frequent fuel shipments, as well as initiating the use of fuels which may be less reliable than the current fuels in use.

Acknowledged by card 8/21/84
pd

Since the new LEU fuels developed by the RERTR program and produced by a manufacturer must be certified or approved by the commission to be used in all of the intended reactors without risk to the health and safety of the public, all of those considerations which would normally be addressed for the individual reactors regarding fuel use in relicensing and technical specification amendments must be addressed in the certification hearings. If approved, the use of the fuel should then automatically be amended into the licenses and technical specifications of those reactors without further hearings. In this way, all of the considerations of use of the new fuel will be taken into account before the fuel is approved for use, and all parties will be spared the considerable expense of identical licensing proceedings for a number of reactor facilities.

It might be that setting the enrichment limit not at 20 percent U-235, but at 25 or 30 percent will not produce any change at all in the possible consequences of theft or diversion for the quantities of uranium in a small reactor. At the same time, a somewhat higher limit may make the time of availability of the new fuel much sooner, and may also permit a more reliable fuel to be developed since the fraction of structural material will be greater. An analysis similar to a cost/benefit analysis should be developed to determine what actual enrichment limit of U-235 is acceptable in the quantities involved, and balancing the consequences and risks of theft with the delays, development costs, and reduced reliability for achieving a fully 'low' enrichment of 20 percent.

No new research reactors have been developed by universities or private organizations in the United States for many years, yet new reactors are regularly being built and put into use in foreign countries. I see a definite trend of the United States falling behind in the development and use of reactors for research. I am very happy to see that the proposed rule would guarantee the possibility of constructing future reactors when they have a 'unique purpose' which could only be achieved with highly enriched fuel. However, because this proposed rule has the overriding effect of discouraging all new non-power reactor development in the United States, the federal government should have a concomitant program of encouraging non-power reactor development and construction in the United States. This program should include a guarantee that if the reactor is maintained and operated as specified in the license to protect the public, it can continue to be operated for its intended purpose with no unreimbursed financial burdens imposed upon it by the Commission. Without this guarantee, and considering the message given by the proposed rule change, no organization could invest in a reactor system, however useful and unique, in the current regulatory climate.

I have had 18 years of experience with non-power reactors, including 12 years as licensed senior operator and director of a (low enriched) university research reactor, and two years in international safeguards work. While all of the above comments are my own, I feel my opinions are shared by my university colleagues who understand the magnitude and ramifications of this project. I appreciate your consideration of these comments.

Sincerely,

George W. Nelson

George W. Nelson, PhD

DOCKET NUMBER
PROPOSED RULE PR-50 (8)
(49 FR 27769)

UNIVERSITY OF CALIFORNIA, LOS ANGELES

UCLA

BERKELEY · DAVIS · IRVINE · LOS ANGELES · RIVERSIDE · SAN DIEGO · SAN FRANCISCO

SANTA BARBARA · SANTA CRUZ

COMMUNITY SAFETY DEPARTMENT
OFFICE OF RESEARCH & OCCUPATIONAL SAFETY
LOS ANGELES, CALIFORNIA 90024

DOCKETED
USNRC

'84 AUG 16 P2:20

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

August 9, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C., 20555
Attn: Docketing and Service Branch

Re: Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

Dear Sirs:

The majority of HEU in U.S. research reactors is in the form of uranium oxide or uranium/aluminum alloy. In all cases, the weight percentage of uranium in the fuel is so low that it would be impossible to make a fast critical assembly (i.e. a weapon) without using hundreds or thousands of pounds of the reactor fuel. In fact, I would guess that there isn't enough HEU research reactor fuel, of any single type, in existence to make a fast critical mass.

Therefore, in order to use such fuel for devious (i.e. terrorist) purposes, the HEU would have to be separated from the base fuel material. While such separation is certainly not impossible, it is difficult and potentially quite dangerous. This is particularly true, in light of the fact that most of the HEU research reactor fuel is in operating reactors and hence is highly radioactive. The theft, transportaton, and subsequent refinement of such fuel would be very difficult and rather hazardous to the thieves.

In addition, unless very heavy shielding and sophisticated handling equipment were used the location of such highly radioactive material would be relatively easy to locate.

I also have to question whether there have been any credible threats or attempts to divert HEU reactor fuel? I suspect not (since it isn't really a very attractive target), and hence I suspect that this proposed rule is due to either the paranioa of a few highly placed persons or their political response to unfounded, sensationalistic claims that have received a lot of media coverage.

Finally, I have to point out that it is incredibly naive to think that because the U.S. reduces the use of HEU fuel, that other countries

Acknowledged by card 8/17/84 pd

would do likewise. The U.S. ban on power reactor fuel reprocessing (to reduce the flow of plutonium in commerce) has not deterred *any* other country. The U.S. imposed restrictions on using research reactors supplied to foreign countries for plutonium production are a joke and country after country have ignored such restrictions. The U.S. attempts to limit the development of new, cheaper isotope separation technologies (e.g. West German centrifuge technology) are ignored. In view of the failure of all past unilateral actions taken by the U.S. to control fissionable material, it is more than naive, it is stupid to think the conversion of U.S. research reactors to LEU would have any affect on other countries.

The conversion from HEU to LEU appears to have little if any assured benefit, but it certainly would have a very high cost. The cost is not so much in dollars and manhours (though those costs would be quite high), but in the certain loss of many research reactors. Many University research reactors that are used primarily for teaching would shutdown if they were required to expend *any* money or manhours to convert to LEU fuel. The University people I know, see *no* benefit to such a conversion, and hence any cost to them is too high. The U.S. would thus lose a significant fraction of its teaching, training, and research capability in the nuclear energy field, definitely a high price to pay for an unrealistic expectation of an uncertain benefit.

If there is classified intelligence information which indicates that there is a realistic potential for diversion of unirradiated HEU research reactor fuel, then perhaps the NRC or DOE should be considerably more restrictive on both the amount of fresh fuel a research reactor can have in storage and on the shipping regulations covering such fuel. In the absence of any indication of a realistic threat of diversion, I don't think the public testimony of those folks who support HEU to LEU conversion is at all convincing and I urge the NRC to reconsider this proposed rule.

Very Truly Yours,

Walt F. Wegst

Walter F. Wegst, Ph.D
Director, Research and
Occupational Safety

EIP/California
Eastern Columbia Building #829
849 South Broadway
Los Angeles, California 90014-3573
(213) 622-0029

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

⑩

'84 AUG 17 P12:28

DOCKETING & SERVICE BRANCH

Secretary of the Commission
Nuclear Regulatory Commission
Washington D.C. 20555

Attention: Docketing and Service Branch

August 14, 1984

Dear Secretary,

It is my firm conviction that your proposed rule to require some 30 research reactors to convert from HEU fuel to LEU fuel is crucial and must be adopted without dilution. Any chance, even remote, that an academic tool could be comandeered for bomb-making purposes must be eradicated.

I believe that this rule should take effect as soon as possible, and that no reactors should be exempted. In light of the fact that the University of Maryland and other schools have already made a successful switch, I believe the rule has quite a bit of evidence in its favor.

Thank you for your consideration. I hope that soon all small reactors are operating on LEU fuel.

Sincerely,

Howard Kushnir
Regional Director

Acknowledged by card. 8/24/84
pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) ⑫

City of Detroit
CITY COUNCIL

MARYANN MAHAFFEY
COUNCIL MEMBER

'84 AUG 20 P12:39

August 14, 1984

Docketing and Service Branch
Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555

To Whom It May Concern:

I am writing in support of the proposed rule requiring nuclear research reactors to convert from highly enriched uranium to low enriched uranium. I also believe the conversions should be effective as soon as possible, not in five or ten years.

The University of Michigan is already in the process of conversion, yet the existence of 23 universities using HEU is a threat to all of us.

I urge you to eliminate this threat by implementing the proposed rule.

Sincerely,

Maryann Mahaffey
Maryann Mahaffey, ACSW

MM:lh

Acknowledged by card 8/21/84
pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

'84 AGO 17 P4:41

[illegible]

August 15, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Attention: Docketing and Service Branch
Washington, D.C. 20555

Dear Sir:

This letter concerns the Proposed Rule regarding the use of Highly Enriched Uranium in Domestic Research and Test Reactors. The notice indicated that comments are due by September 4, 1984. On behalf of the research reactor members of the Reactor Operations Division - American Nuclear Society, I request that the comment period be extended sixty (60) days.

Determination of the impact of the rule on the operations of research reactors will required very careful analysis in order to present meaningful comments. The limited resources at research reactors are reduced at this time due to the summer recess at most facilities. Hence, it will be most difficult to provide information to the Commission by September 4, 1984. In addition, the Training Research and Test Reactor organization is planning their annual meeting August 22-24, 1984. At the meeting the proposed rule will be fully explored for its implication. The discussion will enable each participant to more fully develop his comments.

Thank you for your consideration of this matter.

Sincerely,

Paul F. Collins

Paul F. Collins, Chairman
Reactor Operations Division

cc: A. Francis DiMeglio
Rhode Island Atomic Energy Commission
Rhode Island Nuclear Science Center
South Ferry Road
Narragansett, R.I. 02882

Acknowledged by card 8/21/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49FR 27769) (13)

August 16, 1984

End Nuclear Dumping in the Pacific
614 Gretna Green Way
Los Angeles, CA 90049

DOCKETED
USNRC

'84 AUG 20 P12:55

DOCKETING & SERVICE
BRANCH

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555
Attn.: Docketing and Service Branch

To the NRC Docketing and Service Branch:

End Nuclear Dumping in the Pacific strongly supports your recommendation for the conversion of the nuclear reactors under your jurisdiction (largely the ones on college campuses) to readily available and plentiful low-enriched uranium fuel. There has been such a conversion at the Univ. of Maryland which was very successful and smooth, while the Univ. of Michigan is presently undergoing such a wise conversion. The cost of converting to LEU fuel is tiny compared with the cost of making properly secure the nuclear reactors on college campuses.

With the publicity surrounding the 1984 Summer Olympics in Los Angeles, many people are familiar with the controversy over the U.C.L.A. reactor and more aware of the potential for a nuclear device to be made from the fuel and by-products of this and other campus reactors. Domestic targets, possibly nuclear reactors themselves, might well be the target of someone who might steal this dangerous, laxly-guarded material from our campuses.

We need prevention of this fuel being diverted into the production of a bomb, not scholarly probability assessments. You are as aware as I about the disappearance of bomb-grade nuclear material which has ended up in the Middle East, among terrorist groups, and elsewhere. The example of converting U.S. college reactors to LEU fuel would set a fine precedent, and make more secure U.S. corporate investments and facilities on many continents.

The argument that vital research cannot take place with using just LEU fuel is ridiculous. Obviously, the NRC does not determine what goes on at military-related facilities. Thus, I oppose the suggestion that our national security will be impaired unless a few of the reactors under NRC jurisdiction continue using HEU fuel. The safer LEU fuel is available now: let's move forward toward conversion. The Department of Energy could quite likely pay for the conversion, while you are likely aware that New York Congressmember Ottinger (Chair of the House Energy and Commerce Subcommittee on Energy Conservation and Power) has offered to sponsor a bill to pay the costs for this vitally necessary conversion.

Sincerely concerned,
Bruce Campbell
Bruce Campbell
for
End Nuclear Dumping in the Pacific

Acknowledged by card 8/21/84
pd

1642

DOCKET NUMBER
PROPOSED RULE PR-50 (20)
(49 FR 27769)

August 16, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, DC 20555

DOCKETED
USNRC

'84 AUG 27 P12:27

Re: Rule Making on Low-Enriched Uranium Fuel in Non-Power Reactors

Dear Sir,

Attached you will find my testimony that I presented on June 12, 1984 before the Advisory Committee on Reactor Safeguards on

THE NEED TO CONVERT DOMESTIC RESEARCH REACTORS FROM HIGHLY ENRICHED TO LOW-ENRICHED URANIUM FUELS.

Because of the desire to make our national policy on HEU consistent with our rules on the export of HEU, I hope that the NRC rules will be carried out on most of the reasearch reactors fairly promptly, within five years from the present time. It is my conviction that funding will be available from the U.S. Congress to assist these conversions; the Congress will respond to accelerate the pace of conversion. Because of this judgement, I don't think the phrase "economics of conversion" should be used to avoid the change. Of course, there will be a few reactors where the technical feasibility will be more difficult, but this exemption should be true only in a few cases. If I can be of any assistance, please do not hesitate to contact me.

Sincerely,

David Hafemeister

David Hafemeister
553 Serrano
San Luis Obispo, CA 93401
(805-544-5096)

Attachment: June 12, 1984 testimony

Acknowledged by card 8/29/84 pk

STATEMENT OF DR. DAVID W. HAFEMEISTER

Before the Advisory Committee on Reactor Safeguards
Nuclear Regulatory Commission
Regarding the Need to Convert Domestic Research Reactors
from Highly Enriched to Low-Enriched Uranium Fuels
June 12, 1984

BIOGRAPHY BRIEF. From 1962 to 1966, I used research reactors at the University of Illinois and at the Los Alamos Scientific Laboratory to carry out experiments in nuclear and solid state physics. From 1975 to 1977, I was Science Advisor to Senator John Glenn, who was the Ad-Hoc Chairman of the Governmental Affairs Committee on Nonproliferation matters. From 1977-79 I was Special Assistant and Expert Consultant to Under Secretary of State Lucy Benson and Deputy Under Secretary Joseph Nye, working primarily on nonproliferation matters. I am presently a Visiting Scientist at the Massachusetts Institute of Technology, and I am Professor of Physics at the California Polytechnic Unviersity, San Luis Obispo, California. My Curriculum Vitae is attached.

CONCLUSION: It is my opinion that research reactors in the U.S. should be required to convert from high-enriched uranium fuels (HEU) to low-enriched uranium fuels (LEU). The lower flux reactors can convert to the presently available uranium-aluminum fuels, and the higher flux reactors can convert to the uranium-silicon fuels which will be available in a few years. Exceptions to this conversion should be allowed only upon a finding that the new fuels would not be feasible. This conclusion is based on (1) requirements for adequate physical security, (2) consistency with the national policy on nonproliferation, and (3) technical availability of the new LEU fuels. If the reactor fuels are not converted to LEU, then the radiation barrier for each bundle should be maintained at a minimum of about 100 REM/hour (unshielded at 3 feet).

WEAPONS IMPLICATIONS. There is general agreement that highly-enriched uranium and plutonium are dangerous in that nuclear weapons can be fabricated from these materials. The American Nuclear Society acknowledges this problem. In a recent study (C. Starr, Science 224, 952 (1984)), the American Nuclear Society stated that:

> "There are now about 350 research reactors in about 50 countries, of which 25 are developing countries. Many of these reactors are too small to produce signficant amounts of plutonium. However, most of them have been supplied with highly enriched uranium fuel, which, in principle, might be accumulated to make a single nuclear device. This possiblity is now being precluded by conversion to lower enrichment (less than 20 percent) designs."

HEU WEAPONS. Since HEU can be used directly to fashion a clandestine fission explosive by either a state or a terrorist group, the use of HEU should be minimized, and when HEU is used it must be under adequate physical security. LEU is considerably less effective as a nuclear explosion since (1) it requires about 15 times more LEU uranium than HEU uranium (with reflectors), (2) about 3 times more U-235, and (3) it is much more difficult to develop and deliver a nuclear weapon that consists of hundreds of kilograms of uranium.

HISTORICAL PERSPECTIVE. The Indian device of 1974 hightened concerns in the U.S., the Congress, and the Executive Branch. Shortly after this event, about one-half dozen contracts were signed to export enrichment and reprocessing plants to smaller nations, many of which did not have an economic need for such facilities. In response to these events, the Congress commissioned a study by the Office of Technolgoy Assessment. The OTA report (1977) acknowledged that solutions to nuclear nonproliferation are not simple by stating that:

> "There are no single or all-purpose solutions; no short-cuts. A viable nonproliferation policy will require the coordinated, planned use of a wide variety of measures."

THE RESPONSE OF THE CONGRESS. The U.S. Congress (essentially unanimously) responded to this situation by passing the Nuclear Nonproliferation Act of 1978 (NNPA) and the Glenn-Symington Amendment. As a result of these and other actions, the U.S. policy is to minimize the use of HEU in the world. The U.S. government has not exported HEU for lower-flux reactors, and it has asked for conversion to higher density fuels in the future for higher-flux reactors. This program, known as the Reduced-Enrichment Research and Test Reactor Program (RERTR), represents the official policy of the United States aimed at attempting to reduce enrichments of research reactor fuels and thus the amount of HEU in use.

INTERNATIONAL RESPONSE. The summary report of the International Nuclear Fuel Cycle Evaluation (1980) has stated that it is feasible to markedly reduce the uranium enrichment of a great majority of research reactors: INFCE endorsed the conversion of HEU fueled research reactors to lower enrichment.

HEU EXPORT LISCENSES. The U.S. no longer will accept new commitments to export HEU for foreign research reactors. New research reactors are being sold only with LEU fuels. A few commitments for HEU for high-flux research reactors are being carried out on an interim basis to Belgium, France, Holland and Japan, but, we have asked them to convert to LEU, and, as I understand it, they have agreed to do so. Recently, the U.S. did export 0.9 kg of HEU to the Canadian-built SLOW POKE reactor in Jamaica, but the Canadians have stated they will not request any more HEU for their research reactors.

HEU AND THE APPLICATION OF THE GLENN-SYMINGTON AMENDMENT. This amendment denies military and economic aid to those non-nuclear weapons states that (a) explode a nuclear device, or (b) build enrichment and reprocessing facilities outside of an international framework. On April 6, 1979, this sanction was applied to Pakistan since it was concluded that Pakistan was building an enrichment plant to produce weapons-grade uranium. This sanction was later removed because of the Soviet invasion of Afganistan. I was intimately involved with this amendment while working with Senator Glenn (joining him in the House-Senate Conference where the House accepted the Senate language), and while working in the State Department (debating its merits before the Deputy Secretary of State, at OMB meetings, writing testimony, etc.) This amendment was adopted without dissent in the Congress. The Congress was, and is, concerned about HEU in unstable places.

HEU IN THE IRAQI REACTOR This reactor was destroyed by Israel in 1981. France no longer will export HEU to Iraq, but they will export LEU to Iraq.

CONSISTENCY IN FOREIGN POLICY. The professional staffs concerned with nonproliferation matters are convinced that it would be helpful to convert U.S. research reactors in order to be consistent with the French, Canadian, and American positions. Interagency meetings at OMB might try to soften this position, but I know of no serious nonproliferation staff member who would disagree with the conversion requirement. As we have seen from the examples of Pakistan and Iraq, nonproliferation can be compromised by other foreign policy concerns. It is true that the carrying out of a sanction against one nation, may well cost us in our diplomatic standing with that nation, and that larger events (such as the Soviet invasion of Afganistan) can push nonproliferation policy the other way, towards ignoring the problem. The beauty of the HEU conversion proposal is that, for at most $15 million, the U.S. can achieve consistency between what we demand of others and what we demand of ourselves. I have found out from personal experience when dealing with nuclear officials of other nations that "moral leadership" quite often does not work in foreign policy, but most of us would agree that being inconsistent by favoring our university reactors with HEU will certainly make the political climate abroad for the HEU to LEU conversions all the more difficult. In the area of nonproliferation policy, the $15 million figure is relatively minor, as compared to other costs in this area.

PHYSICAL SECURITY. Section 10 CFR 73.67(a)(1) states that

> "Each licensee ... shall establish and maintain a physical proctection system that will achieve the following objectives:
>
> (i) Minimize the possibilites for unauthorized removal of special nuclear material consistent with the potential consequences of such actions: and
>
> (ii) Facilitate the location and recovery of missing special nuclear material."

First of all, I would like to address the word "consequences" in (i). The consequences of obtaining HEU could be the development of a nuclear device which could destabilize our international framework of nations. This extremely serious event might kill thousands of people and could be a precursor to an international conflict. Next I would like to address the word "consistent" in (i). To minimize the possibiliites of unauthorized removal in a way which is consistent with the seriousness of the potential consequences of such a removal means that very stringent physical security and recovery techniques must be available. The (hypothetical) intrusion must be site-specific. Is the facility really secure? The time line of possible recovery must be considered. How long would it take for a recovery team to arrive? Would the signal be triggered by the penetration into the building, and would there be time delays before the penetration of the secondary barriers? From where would recovery team come? Would the detection devices be applicable for fuel that was not very radioactive? How far can a vehicle travel during this time to get away with the fuel? What is scan rate of the aircraft? If it is 70 square kilometers per hour, then this would imply a radius of 4.7 km (3 miles). The minimum velocity of the escape vehicle would have to be

$$V \text{ (MPH)} = 3/T$$

where T is the arrival time in hours of the monitoring aircraft after the first signal. If it took one hour after detecting the first signal of the violation to obtain a scanning aircraft above the reactor, the minimum velocity of the vehicle would be 3 MPH. It is difficult to imagine any vehicle being slow enough to get caught under this circumstances. In other words, it would seem that a significant time delay would be needed between the time of first penetration of the building, and the theft of the fuel.

LEU vs. HEU. As we have indicated above, LEU weapons are feasible, but much less likely than HEU weapons. Transporting LEU under an armed guard is clearly less dangerous than the similar transporting of HEU, and certainly the storage of LEU on-site is also considerably less risky than storing HEU on site.

RADIATION BARRIER. As I understand it, the radiation level of a bundle of fuel would drop to about 10 REM/hour (unshielded at 3 feet) in about 7 days after shutdown. It would appear necessary to maintain higher levels of radiation, say about 100 REM/hour at 3 feet, to discourage theft.

CONCLUSIONS: Research reactors in the U.S. should be required to convert from HEU to LEU. The lower-flux reactors should do this within the near term, and the higher-flux reactors should convert to LEU when the U-Si fuels are available. Exceptions should be permitted only for the very rare case where it can be shown that this conversion is infeasible. If the reactors are not converted to LEU, then the reactors should be operated so that the fuel bundles will have a high radiation barrier, of the order of 100 REM/hour at 3 feet.

David W. Hafemeister

Professional Qualifications

1. Education:
    a. Bachelor of Science degree in Mechanical Engineering from Northwestern University, 1957
    b. MS. and Ph.D. in Physics, University of Illinois. 1959, 1964
    c. Post-Doctoral Fellowships:
        Los Alamos Scientific Laboratory (1964-66)
        American Association for the Advancement of Science Congressional Fellowship (1975-1976)

2. Employment
    a. Mechanical Engineer, Argonne National Lab (1957-58)
    b. Physicist, Los Alamos Scientific Laboratory (1964-66)
    c. Assistant Professor of Physics, Carnegie-Mellow University (1966-69)
    d. Associate Professor of Physics (1969-72)
        Professor of Physics (1972-)
        California Polytechnic University, San Luis Obispo, CA
    e. Visiting Professor of Physics
        University of Groningen, The Netherlands (1972, 1980)
    f. Legislative Assistant and Science Advisor to Senator John Glenn
        U.S. Senate (1975-77)
    g. Special Assistant to Under Secretary of State Lucy Benson and
        Deputy-Under Secretary Joseph Nye, U.S. Department of State (1977-1979)
    h. Visiting Scientist, Mass. Instit. of Technology (1983-4)

3. Experience with Nuclear Non-Proliferation Matters
    a. U.S. Senate: After the detonation by India of a nuclear device in 1974, the Committee on Governmental Affairs of the U.S. Senate held extensive hearings on the "Export Reorganization Act of 1975" which dealt with nuclear nonproliferation. It was my job to be the full-time staffperson to the Ad-hoc Chairman of the Committee, Senator Glenn, on hearings and mark-up of the act. I was Senator Glenn's main advisor on nuclear non-proliferation matters.
    b. Department of State: In 1977, I was appointed as one of two Special Assistant on the issue of nuclear nonproliferation to Under-Secretary Benson and Deputy-Under Secretary Nye. Dr. Nye had the lead role for nuclear non-proliferation in the Executive Branch and at the London Nuclear Supplier Negotiations.

        During this time, I was intimately involved with the drafting and passage of the Nuclear Non-Proliferation Act of 1978, participating in the Department of Energy's Non-proliferation Alternative Systems Assessment Program (NASAP), and dealing as a representative of the Under Secretary with officials of other nations' nuclear programs.

In addition, I was the lead State Department delegate to Working Group 8 (Advanced Fuel Cycle and Reactor Concepts) of the International Fuel Cycle Evaluation (INFCE) which was held at the International Atomic Energy Agency (IAEA) in Vienna. Subgroup C of this Working Group had as its sole task the assessment of methods of reducing proliferation risks associated with research reactors. DOS member of interagency Subgroup on Nuclear Exports (SNEC).

4. Publications

a. Nuclear Non-Proliferation:

i. "Nonproliferation and Alternative Nuclear Technologies", Technology Review 81, 58 (December 1978).

ii. "Science and Society Test V: Nuclear Nonproliferation", American Journal of Physics 48, 112 (1980)

iii. prime author/editor of the Presidential Report to the Congress on the environmental impacts associated with nuclear exports abroad (1980)

iv. co-author/editor of the Supplement Nuclear Research and Development Export Activities to ERDA 1542 (U.S. Nuclear Export Activities), September 1979.

b. Solid State and Nuclear Physics:
20 articles; four book chapters; one book

c. Energy Technology and Policy:
15 articles, co-edited 2 books

DOCKET NUMBER PROPOSED RULE PR-50
(49 FR 27769)

(16)

Allen Blumenthal
805 E. Berkeley Ave.
Santa Ana, Ca. 92707
August 21, 1984

'84 AUG 24 A9:55

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555
Att: Docketing & Service Branch

Dear Secretary:

I am writing this letter in support of your proposed rule requiring research reactors to convert to low enriched fuel (LEU). Reseach reactors are often in populated communities and colleges. As such, they pose serious problems of safety, sabotage, theft, and terroism. It is too easy to obtain access to these areas and thus pose the ~~treat~~ threats just discussed. It makes it too easy for "fringe groups" to obtain and use this fuel for their own purposes.

The other alternative, massive security systems, is just as uninviting. They are expensive and take away needed funds from the educational and research areas of the universities and nuclear research itself. Furthermore, the academic communities where the research reactors reside need an open atmosphere and access to facilities. Any sedurity measures necessarily takes away from this and the amount that is required without the LEU change is much too high a cost for the universities. Thus inadvertintly the use of HEU threatens the open atmosphere that is needed for the exchange of new ideas that makes for our democratic society.

Therefore, the new rule achieves several important goals. It reduces the danger and risk posed by these reactors to the surrounding communities. It allows these community/colleges~~s~~ to remain the open and free citadels of learning while allowing nuclear research, with a minimum of restrictions, to continue. Everyone wins. I think you should be commended for proposing the rule and hope you will approve it.

Sincerely,

Allen Blumenthal

Allen Blumenthal

Acknowledged by card 8/24/84
pd

PROPOSED RULE PR-50 (37)
(49 FR 27769)

August 21, 1984

Attn: Docketing and Service Branch
Secretary of the Commission
U.S Nuclear Regulatory Commission
Washington, D.C., 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

'84 SEP -5 P3:42

Dear Sir:

I am writing to support conversion of all nuclear reactors which use highly enriched uranium. Let us not bungle this nuclear fiasco any further. Highly enriched uranium ~~is a~~ serves as bait for terrorists who want to threaten the peaceful transformation that is now taking place. The financial cost of conversion is insignifigant compared to the potential costs involved if a succesful theft of fuel were carried out.

Please, be thoughtful and sensitive. Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

In order to be effective, this action must be non-voluntary and it must be implemented properly.

Thank you for taking this action,
Christopher Ortolano
115 Otis Street
Santa Cruz CA 95065

Acknowledged by card 9/5/84 dd

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)
(18)

Graduate Assembly
Anthony Hall • University of California • Berkeley, California 94720 • 642-2175

'84 FEB 27 A11:10

21 August 1984

Attn: Docketing and Service Branch
Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

I am writing you to express my concern over the 23 nuclear reactors used around the country on various university campuses for training nuclear engineers and for medical research.

As you know, the Highly Enriched Uranium (HEU) Conversion Rule (49 Federal Register 27769) requires that these nuclear research reactors convert from HEU to Low Enriched Uranium (LEU). The HEU used now in the reactors is dangerous not only because it is weapons-grade material, and poses a potential threat should it get into the wrong hands, but this fuel must also be transported through highly populated areas both to and from the reactor sites.

A New York Times article states that the conversion would cost about $15 million. Such a cost is petty cash when compared to the social costs involved should the fuel be stolen or allowed to escape through transport.

I therefore urge you to take immediate action on the implementation of the HEU Conversion Rule. Do not leave it up to each campus to decide for itself. Voluntary action in this case will not best serve to benefit the majority of U.S. citizens.

Thank you for your time and consideration.

Sincerely,

RHA R

Robert A. Rice
Co-chair, External Affairs

Acknowledged by card 8/29/84 pd

DOCKET NUMBER PROPOSED RULE PR-50 (49 FR 27769) (19)

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

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GRADUATE STUDENTS' ASSOCIATION
244 MILLBERRY UNION
UNIVERSITY OF CALIFORNIA

SAN FRANCISCO, CALIFORNIA 94143

'84 AUG 27 P4:52

August 22, 1984

Attn: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

As representative to the University of California Student Body President Council from the San Francisco campus, I am writing to support the regulation that would require owners of non-power reactors to use low-enriched uranium fuel rather than high-enriched uranium fuel.

The regulation in question would reduce the threat of theft of weapons grade material and would encourage a reduction in the use of highly enriched uranium fuel world wide. If implemented, it could be a significant achievement in nuclear non-proliferation.

Expedience in this matter is of utmost importance. Thank you for your consideration.

Sincerely,

Louise Bourassa

Louise Bourassa
President, External Affairs

Acknowledged by card. 8/29/84 pa

Robert De Bolt
129 Sunnyside Ave
Santa Cruz, CA 95062

DOCKET NUMBER PR-50
PROPOSED RULE (49 FR 27769) (14)

'84 AUG 23 AM11:15

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to support conversion of all nuclear reactors which use highly enriched uranium.

Most universities have between 4 and 20 kilograms of highly enriched uranium in storage and stringent security measures necessary to adequately protect such sensitive materials is lacking at many of the facilities.

This material, which could be used by a terrorist group to build an atomic weapon, poses an unnecessary threat to national and international security. It is important that we convert these reactors before the fuel is stolen and used to build an atomic weapon. The financial cost of conversion is insignificant compared to the risk of such a threat.

Conversion of these reactors and removal of the weapons-grade fuel should be carried out as soon as possible on a non-voluntary basis. If implemented, it could be one of the most significant achievements in nuclear non-proliferation in recent years and help to discourage the use of HEU fuel world-wide.

Thank you for your consideration.

Sincerely,

Robert De Bolt

Acknowledged by card 8/24/84 pd

PR-50 (23)
(49 FR 27769)

UNIVERSITY OF CALIFORNIA, LOS ANGELES UCLA

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CENTER FOR INTERNATIONAL AND STRATEGIC AFFAIRS
LOS ANGELES, CALIFORNIA 90024
(213) 825-0604

RE: HEU Conversion Rule
(49 Federal Register 27769)

'84 AGO 30 A11:42

August 23, 1984

Attn: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington D.C. 20555

Dear Sirs:

It has come to my attention that the Nuclear Regulatory Commission has before it a proposed rule that would require about thirty nuclear research reactors to convert from HEU to LEU. I have recently written a book on the challenges posed by nuclear proliferation and subnational nuclear threats (*Global Nuclear Energy Risks: The Search for Preventive Medicine*, Westview Press, forthcoming November 1984). It is my professional judgement that the elimination of HEU from lightly guarded research reactors is a prudential step to prevent diversion. American action in this regard would encourage other nations where the danger of diversion may be more acute to do likewise. Accordingly, I urge you to adopt and apply the rule on a mandatory basis without delay.

Thank you for your consideration.

Sincerely,

Bennett Ramberg

Bennett Ramberg Ph.D.
Research Associate

[illegible] 9/4/84
pl

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NATIONAL
LAWYERS
GUILD
Los Angeles Chapter

PR-50 (15)
(49 FR 27769)

'84 AUG 24 A10:40

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
attn: Docketing and Service Branch

RE: H.E.U. Conversion Rule (49 Federal Register 27769)

Dear Sir or Madame:

The Los Angeles Chapter of the National Lawyers Guild has voted to support the conversion of all nuclear reactors currently using highly enriched uranium.

The use of highly enriched fuel is an unnecessary danger to public security because the reactors are largely unprotected. Further, the continued existence of bomb grade fuel hampers this country's and the world's ability to survive in the nuclear age.

The National Lawyers Guild supports any move, including the proposed rule, that lessens the threat of weapons grade fuel being used against human beings. The proposed rule is one step in that direction. Conversion of these reactors and removal of the weapons grade fuel can be a signal to the rest of the world that the United States takes seriously the problem of nuclear weapons proliferation. This proposal could help discourage the use of H.E.U. fuel world wide.

The need for conversion cannot be taken lightly. To effectuate the purpose of the proposed rule, it should be mandatory and implemented immediately. No exemptions should be allowed.

Thank you for your consideration of these comments.

Yours truly,

ANTHONY MISCHEL
Executive Committee
Treasurer

ASM:sbc

Acknowledged by card 8/24/84 pd

NLG
Founded 1937

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) ㉑

c/o NOVA
7800 Airpark Road
Gaithersburg, Maryland 20879

August 24, 1984

DOCKETED

Secretary to the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
attention: Docketing & Service Branch

'84 AUG 28 A10:13

RE: Proposed Rule to Convert Research Reactors Using
Highly Enriched Uranium to Non-Weapons-Grade Fuels
(49 Federal Register 27769)

Dear Sir:

I write in support of a strong regulation to require expeditious, mandatory conversion of research reactors now using highly enriched uranium. Please consider the enclosed testimony given before the Commissioners as my detailed comments in regards the proposed rule.

Sincerely,

Theodore B. Taylor

Dr. Theodore B. Taylor

enclosure: "Statement of Dr. Theodore B. Taylor
Regarding the Need to Convert Domestic Research
Reactors From Highly Enriched to Low-Enriched
Uranium Fuels"

Acknowledged by card 8/29/84 pd

PR-50 (49 FR 27769) (24)

Associated Students of the University of California

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STUDENT BODY PRESIDENTS' COUNCIL

DOCKETED
USNRC

'84 AGO 30 A11:43

Kayleen Kott
359 Memorial Union
University of California
Davis, California 95616

August 24, 1984

Att: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

The Student Body Presidents' Council of the University of California, representing 140,000 students on nine campuses, strongly supports the proposed regulation to require conversion of all non-power reactors from highly enriched uranium (HEU) to the safer low enriched uranium (LEU). Enclosed please find a copy of an SBPC resolution 8/18/84 supporting immediate conversion allowing no exemptions thus enhancing national and international security.

The SBPC does not understand the NRC's preoccupation with the cost of conversion. We understand that financial considerations are important "in determining the availability of LEU fuel (which for many facilities is free or relatively inexpensive due to oversupply at similiar facilities) and schedule for conversion. However, it does not seem appropriate that the NRC concern itself with the "economics of conversion" as much as it should serve the public by assuring both public health and safty. If the NRC passes stringent regulations the federal government will be encouraged to provide funding such as the Department of Energy has shown with $2 million to gegin conversion in the first year. The cost of conversion, in the first year. The cost of conversion, no matter who pays, is minimual compared to the cost of theft or accident of these research reactors. Plus consider the cost of improving security at these research reactors to adequately protect this valuable and vulnerable material.

The time frame proposed by the NRC is of concern to the students of California. According to the proposed rule a licensee would not even be required to submit a proposed schedule for conversion for 12 months after passage of this rule. We believe one year is too long to wait to begin actual conversion. Furthermore this regulation does not establish a date by which licensees must complete conversion. The scheduling of shipping casks should not effect the time frame since transportation time even accross country could be no more than a few weeks. Also conversion dates should not be effected by federal funding since the individual licensees have a responsibility to assure that their reactors comply to safty regulations.

The idea of "generic envelopes of safety limits for the several types of non-power reactors" is not acceptible to SBPC, although we do see the need for generic safety analysis for fuels. Licensees should not be required to merely submit to

9/4/84 pd

a set of vague generic rules but rather be required to prove conversion has created no reduction in safty. If there are any questions as to the safty of the reactors due to conversion the public should be allowed to address these questions in a public hearing. The right to public hearing on safty issues is guarenteed by the Atomic Energy Act and should not be forfeited in this regulation or any regulation. Also licensees should be required to conduct an environmental impact statement for any questions of safty or health. This statement like the "analysis showing that...normal operating and postulated accident conditions... fall within the limits" must be carefully checked by the NRC and be available for public inspection.

The posibility for exemptions seems overly lenient in this regulation. Reactors with a "unique purpose" could be exempt from conversion which could diminish the intent of the regulation which is to enhance national and international security. The regulation states reactors with "a special experiment or program" would be a candidate for exemption. One experiment should not overturn this needed regulation. Those research projects based on neutron flux levels or spectra are attainable with LEU fuels as well as HEU fuels with only slight modifications.

The NRC is encouraged to require MEU (medium enriched uranium) as close to 20% in those very rare cases where LEU, below 20%, is not possible. However, in almost all domestic research reactors conversion below 20% is possible at this time. For this reason the "continued success of the DOE funded RERTR program" although desirable is not cruxial to the success of HEU conversion.

In summary, the SBPC makes the following recommendations.
The NRC base its decision for conversion of non-power reactors on the safty and health of the public and not on economic considerations.
The timeframe to submit schedule for conversion be shortened and that the NRC set a date for reactors to complet conversion.
There be no generic envelopes of safety limits but rather require licensees to prove no reduction in safty has been created by conversion.
The public retain the right to public hearings on any questions of public safty.
No exemptions be granted for domestic conversion.

Sincerely yours,
Kayleen S Kott
Kayleen Kott, Chair
University of California
Student Body Presidents' Council

enclosed: SBPC resolution 8/18/84

Associated Students of the University of California

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STUDENT BODY PRESIDENTS' COUNCIL

RESOLUTION

Supporting the Proposed Rule by the Nuclear Regulatory Commission on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

WHEREAS, 31 non-power nuclear reactors are licensed in the United States to use highly enriched uranium (HEU)- 25 are owned by universities including one at UCLA and one at UC Santa Barbara, 5 are owned by private corporations and 1 is owned by the U.S. government; and

WHEREAS, highly enriched uranium can be used without further significant processing and without extensive expertise to build nuclear weapons; and

WHEREAS, the security level at these facilities especially at those on university campuses are not sufficient to even moderately protect from a threat of theft; and

WHEREAS, the threat of terrorism is rapidly escalating world-wide and HEU could sell for over $100,000 per kilogram on the black market; and

WHEREAS, the United States government has spoken out around the world for the reduction of HEU, while at the same time the U.S. exports about 600 kilograms annually (the most in the world) and has not made an effort to limit the almost 500 kilograms of HEU within the U.S.; and

WHEREAS, the reduction of HEU within the U.S. may provide an example and incentive for other nations to emulate thus reducing the danger of international terrorism; and

WHEREAS, the low enriched uranium (LEU) fuels can be used without significant reduction in performance or research potential; now, therefore, be it

RESOLVED, that the Student Body Presidents' Council supports immediate conversion from HEU to LEU internationally and especially within the United States and that the rule must allow no exemptions if it is to accomplish its goal of enhancing national and international security.

8/18/84
KJG

DOCKET NUMBER
PROPOSED RULE PR-50 (35)
(49 FR 27769)

260 High St.
Santa Cruz, California
95060

'84 SEP -5 P3:33

August 25, 1984

Attention: Docketing & Service Commission
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington D. C.   20555

Dear Sir,

I wish to support conversion of all nuclear reactors which use highly enriched uranium. Because this material can be used in atomic weapons and could fall into the hands of terrorists, I consider it's use to be very hazardous. These conversions should take place without delay,, and no reactors should be exempt from the rule. Not only would this ruling help discourage the use of this sort of fuel worldwide, it would be a first step in stopping nuclear weapons proliferation.

Sincerely,

Virginia Rusinak

Virginia Rusinak

This letter regarding HEU Conversion Rule
(49 Federal Register 27769)

Acknowledged by card 9/5/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50 (28)
(49 FR 27769)

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

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BOARD OF STUDIES IN
ASTRONOMY AND ASTROPHYSICS
LICK OBSERVATORY

SANTA CRUZ, CALIFORNIA 95064

DOCKETED
USNRC

'84 AUG 31 A11:55

August 26, 1984

Secretary of the NRC
Nuclear Regulatory Commission
Washington DC.

Dear Sir:

It has recently come to my attention that many U.S. nuclear research reactors are fueled with uranium sufficiently enriched to serve as nuclear weapons. Evidently many of there reactors are protected by security systems which could be outwitted or overpowered by unfriendly domestic or alien parties. If even a single primitive nuclear weapon could be fashioned from this reactor fuel, it could result in blackmail attempts and great public anxiety or, worse, in a ~~[illegible]~~ colossal loss of life.

In view of this, the only responsible action for the NRC is to reduce the enrichment of domestic reactor fuel as much and as quickly as possible, regardless of any inconvenience for the reactor operators.

I doubt if many in the US are aware of current NRC discussions on this vital issue, but I am certain that the public would insist on immediate deenrichment if they were aware of the danger we currently face.

Sincerely,
William G. Mathews
Professor of Astronomy & Astrophysics

Acknowledged by card 9/4/84 pdr

1662

DOCKET NUMBER
PROPOSED RULE PR-50 (17)
(49 FR 27769)

Associated Students of the University of California

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STUDENT BODY PRESIDENTS' COUNCIL

'84 AUG 27 A11:10

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to support conversion of all nuclear reactors which presently use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of the fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

But in order to be effective, it must be non-voluntrary and it must be promptly implemented.

Thank you for your consideration.

Sincerely,

Raymond R. Cruz

External Affairs President of the
University of California, Riverside

Acknowledged by card. 8/29/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50 (33)
(49 FR 27769)

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO   SANTA BARBARA • SANTA CRUZ

Kevin Gillis
REPRESENTATIVE TO THE
STUDENT BODY PRESIDENTS' COUNCIL

CAMPUS ACTIVITIES OFFICE
SANTA CRUZ, CALIFORNIA 95064

August 27, 1984

'84 SEP -4 P4:55

Att: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing in support of a rule requiring the conversion of all nuclear research reactors from weapons grade (highly enriched) uranium to the non-bomb grade (low enriched) uranium. The students of the University of California at Santa Cruz are concerned with the potential threat and danger of using weapons grade uranium on university campuses with very minimal security.

The NRC should focus its decision on public health and safety concerns and not on the cost of conversion. The cost of conversion is minimal compared to the potential cost and damage in the event of a terrorist attack or a natural disaster.

The use of "generic envelopes of safety limits" is unwise in our view. The NRC should require that the research reactors prove that conversion has not reduced the reactors safety. Whenever there is a question of public health or safety the public should be allowed to address these questions through a public hearing.

The students of UC Santa Cruz encourage the Department of Energy's RERTR program. However, at present technology exists to convert all HEU research reactors to LEU fuel. Thus HEU conversion should continue regardless of the DOE's decision to fund the RERTR program.

We are also concerned with the time frame for conversion and the possibility of exemptions. The regulation requires the licensees to submit a proposed schedule of conversion within 12 months of the rules passage. One year is too long. These proposals should be submitted within a few months and the NRC should establish a date by which conversion must be completed. The possibility for exemptions should be strengthened. If the purpose of the regulation is to promote national and international security, then any exemptions impede that purpose.

The 7,000 graduate and undergraduate students of the university of California at Santa Cruz encourage unanimous support and enforcement of convession of HEU fuel to the safer LEU fuel.

Sincerely yours,
Kevin J Gillis
Kevin Gillis
Social Responsibility Committee

Acknowledged by card..9/5/84....pl.

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(27)

27 August 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555

DOCKETED
USNRC

RE: PROPOSED RULE ON HIGHLY ENRICHED URANIUM

'84 AGO 31 A11:13

Dear Sir:

Following are comments on the NRC's proposed rule limiting use of highly enriched uranium in domestic research and test reactors (Federal Register, July 6, 1984).

The proposed definition of "unique purpose" is too broad. It would permit deferral of conversion based on a single experiment of trivial worth. Instead, facilities requesting exemption should demonstrate that their requirement for HEU is of national security importance equal to or greater in magnitude than the proliferation threat posed by HEU. Moreover, this vital use of HEU should occupy the major portion of reactor usage, and should not be provided by any other reactor in the U.S. which could be contracted for this particular purpose.

The proposed implementation schedule is much too long. Licensees should be required to submit schedules for conversion four months after the rule becomes effective. The rule itself should specify that conversion would be mandatory within twelve months of the time the appropriate LEU fuel becomes available.

Strictly speaking, we believe that the economics of conversion should not influence NRC actions in this instance. If prompt implementation of this rule is in the interest of international security, as we believe it is, economics should not interfere. To put it another way, the highest estimates of the costs of conversion are far less than the costs that would be incurred if HEU were actually stolen from one of these reactors. Incidentally, the costs of conversion will not be significantly greater than the costs of upgrading security, considering the hardware involved and the cost of even a single security guard for twenty years.

Availability of fuel: We note that TRIGA-type LEU is available now to convert those TRIGA reactors which use HEU. In addition, we understand that GA Technologies has the capability of converting reactors which use flat-plate HEU to TRIGA-type LEU. They have in fact already carried out numerous such conversions.

Acknowledged by card 9/4/84 pd

We note also the improvement in safety margins due to the prompt negative reactivity coefficient associated with this fuel. This fuel has of course already been licensed by the NRC and is available now.

Availability of shipping casks should not be a factor in determining conversion schedules, since each conversion requires a cask for only a matter of days. But if there is any reason to believe that a shortage of casks could significantly delay conversions, funding should be sought for an additional cask or two.

Reactor usage should not be a factor in determining conversion schedules. The international significance of conversion must outweigh such considerations.

We oppose the use of "generic envelopes of safety limits." Instead, safety margins should increase or remain equal to those currently approved by the NRC. As long as this is true, no license amend ment should be required for conversion.

If, however, safety margins are decreased by conversion, then a license amendment must be required and the opportunity for public hearing provided.

It is argued that the materials affected by the proposed rule comprise only a fraction of the HEU in circulation. However, we believe that it is important to remove from circulation even "a fraction" of the HEU. It must be recalled how dangerous even a small quantity of this material can be. Furthermore, if we in the U.S. do not take this step, foreign reactor operators will never convert their facilities.

It has been alleged that a required conversion will lead to the shutdown of marginal reactor facilities. Even if this were true, it could not justify weakening the proposed rule which, because of its international security significance, must take precedence, especially over "marginal" facilities.

It has been suggested that the prospect of a required fuel conversion was a factor in the recent shutdown of the UCLA reactor. This is nearly the opposite of the truth. UCLA withdrew its license renewal application one week before hearings on security were to commence. If UCLA had converted to LEU, the security contentions of the Intervenor would have evaporated. UCLA could have sailed through the security hearings and might well have retained its operating license. Conversion would make research reactors easier to license.

It is noteworthy, also, that LEU fuel for UCLA was available for free from the University of Florida, which apparently possesses enough spare LEU to convert all the Argonaut-type reactors in the country.

The international significance of converting domestic reactors from HEU fuel should be clearly understood. When this is done, the various obstacles and objections fade away into relative unimportance. The proposed rule should be promptly and completely implemented.

Sincerely,

Steven Aftergood

Steven Aftergood
Executive Director
Committee to Bridge the Gap

ROGER L. KOHN
534 ELEVENTH STREET
MANHATTAN BEACH, CALIFORNIA 90266

PR-50 ㉚
(49 FR 27769)

August 28, 1984

DOCKETED

'84 SEP -4 P3:47

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Docketing & Service Section

Re: Proposed HEU Conversion Regulation (49 Fed. Reg. 27,769

Dear Sir:

I understand that the NRC is considering a proposed regulation to require conversion of research reactors to low-enriched fuel. I support such conversion, and urge that it be mandatory, immediate, and with only the narrowest of exceptions.

I believe mandatory conversion is necessary because of the risk of theft of high-enriched weapons-grade uranium (HEU) from research reactors and because there are no sufficient countervailing benefits to offset the risk.

Contributing to the risk are at least three policies: (1) University reactors, located as they often are in the university environment, cannot, consistent with the open-access policies of educational facilities, be protected as adequately as can other reactors; (2) It is my understanding that the NRC Staff's view of its practice is that only post-reporting of theft, but not prevention of theft, is required; and (3) the NRC staff has apparently been unwilling to appropriately calculate and enforce the 100 rem-per-hour exemption.

In addition to the unfortunate practice of not requiring protection against theft, I am concerned about the failure of the NRC Staff to date to appropriately calculate and enforce the 100 rem/hr exemption. The exemption's radiation level appears rather arbitrarily determined, and would permit theft of HEU with doses to individual members of a group of thieves not substantially larger than the doses permitted nuclear workers in exceptional circumstances. Even when the regulation is implemented, it is unreasonably interpreted by Staff to allow use of whole-core exposure, when the clearly separable fuel bundle would produce a seriously smaller dose not meeting the 100 rem/hr requirement. Thus the exemption is neither well-founded nor applied in accord with the very letter and spirit of the exemption's intent of preventing theft of fuel bundles. I have attached my declaration in this regard concerning the UCLA research reactor exemption deficiency.

9/5/84 pk

If universities cannot, consistent with budgetary constraints and open-access policies, protect against theft of the weapons-grade uranium that they possess, and since the country and the world surely cannot tolerate diversion of such fuel, then the clear, reasonable, and practicable solution is mandatory, immediate, and enforced conversion to low-enriched uranium.

Please consider my comments, and attached declaration, in your review of the proposed HEU conversion rule.

Sincerely,

Roger L. Kohn

Roger L. Kohn
Ph.D., Applied Physics
J.D., Attorney at Law

Enc.: Declaration of Roger L. Kohn regarding 100 rem/hour exemption miscalculations

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of)
)
THE REGENTS OF THE UNIVERSITY) Docket No. 50-142 OL
OF CALIFORNIA)
) (Proposed Renewal of
(UCLA Research Reactor)) Facility License)

DECLARATION OF ROGER L. KOHN in Support of Intervenor Committee to Bridge the Gap's Brief on the Applicability of Physical Security Regulations to this Licensing Proceeding

I, Roger L. Kohn, declare as follows:

1. I am presently a third-year law student at UCLA School of Law, and expect to receive a J.D. degree in May 1983.

2. I am also a physicist and systems analyst. I received a B.A. degree with honors in physics from Haverford College in 1963, and M.S. and Ph.D. degrees from Stanford University in 1965 and 1968, respectively. I have completed coursework and employment in both experimental and theoretical nuclear physics, and have had twenty years experience in various applications of physics, mathematics, and computer programming. My professional resume, giving my credentials prior to law school, is attached.

3. I have read University's Response to Intervenor's First Set of Interrogatories on Contention XX, August 9, 1982, and Neill C. Ostrander's Fuel Self Protection Calculation dated August 25, 1982, attached to UCLA Representative William H. Cormier's response letter of August 26, 1982.

4. Assuming the values, assumptions, approximations, and equations used in the first two paragraphs of Exhibit "A" of University's Response to Intervenor's First Set of Interrogatories on Contention XX (hereinafter cited as Exhibit "A") or cited in Neill C. Ostrander's Fuel Self Protection Calculation dated 8/25/82, to be correct, I have constructed a calculator program which is capable of calculating dose rates for various times following shutdown. The program produces substantially the same dose rates at delay times of 1, 2, 3, and 4 weeks as those given in paragraph three of Exhibit "A".

5. The match is appreciably better if I assume that the delta-function energy pulse occurs at the end of each week rather than, say, at the beginning of each week (i.e., if the reactor is shut down immediately after a delta-function energy pulse rather than if it is shut down

just before the next one is due). Neither Exhibit "A" nor the 8/25/82 response letter indicates which assumption was made in the model used to produce the numbers in paragraph three of Exhibit "A". I then used this same program to calculate dose rates for delays other than 1, 2, 3, or 4 weeks.

6. The figures in Exhibit "A" are relevant for doses from the (presumed) entire unshielded reactor core. However, on the assumption that the appropriate dose relevant to theft is the dose from a single detached fuel bundle of the twenty-four total bundles in the core, the doses must be redetermined. The Exhibit "A" calculation assumed exposure at a distance of three feet from the core surface and thus four feet from the core center. It also apparently approximated the dose as originating entirely at the core center instead of distributed throughout the core. (It is likely, according to my calculations, that this last approximation will indeed cause less than a ten percent error.)

7. I have assumed in subsequent calculations that, upon separating a single one of the twenty-four core fuel bundles from the remainder of the core, one twenty-fourth of the radioactivity accompanies the bundle. It is possible that in fact some bundles are more radioactive than others at the time of a shutdown. In the absence of any data in the supplied information regarding radioactivity distribution in the core, I have assumed the distribution to be homogeneous. This is conservative with respect to fuel self-protection since the thief, equally uninformed, might reasonably assume the outer bundles to be safest and remove them; my assumption of homogeneity produces a bundle dose rate higher than these possibly below-average outer-bundle dose rates.

8. The exposure due to a single fuel bundle at a distance of three feet from that bundle will then be less than that due to the whole core by a factor of twenty-four; but it will also be greater by a factor of $(4/3)^2$ due to the decreased distance to the center of the radiating source, assuming (as does Exhibit "A") that all radiation equivalently originates at the source center.

9. My results are as follows (please see next page):

time after shutdown	seconds							100
	hours						8	
	days	28	21	14	7	1		
dose rate, r/hr at three feet	Exhibit "A" whole core (for comparison)	83	91	107	142			
	core, end-of-week pulse	88	98	114	149	452		
	core, beginning-of-week pulse	83	91	102	122	174		
	single fuel bundle, end-of week pulse					33.5	92	
	single fuel bundle, beginning-of-week pulse							34

10. All other things being equal, it is more conservative to assume pulses in the beginnings of the weeks, since this yields lower dose rates. The conservative single fuel bundle dose at three feet is only (approximately) 34 r/hr at the shortest delay following shutdown for which the equation in Exhibit "A" is valid, i.e. 100 seconds. For the least conservative situation, i.e. where the reactor is shut down immediately after a delta-function energy pulse, a dose rate of 100 r/hr at three feet occurs for a single fuel bundle only following delay times after shutdown of less than approximately eight hours.

11. If the weekly-period model is used in lieu of an actual operating schedule, the safest assumption would be the conservative one, i.e. that each week's non-constant fraction of the reactor energy is generated early in the week, and that if the reactor is suddenly shut down and the fuel bundles removed, the energy for the most

recent week was generated nearly a week previous to that shutdown. In such a case, using the same numbers, equations, and approximations as those in Exhibit "A" and the subsequent letter, a single detached fuel bundle cannot be considered theft-proof by virtue of a sufficiently high dose rate, to wit, one of at least 100 r/hour at three feet.

12. The weekly-periodic function assumed in Exhibit "A", 3a), is only a reasonable, conservative approximation to the real operation if the reactor is in fact operated to generate at least 200 kWh of energy in each of the weeks preceeding the shutdown.

13. I have not at this time independently verified the accuracy or applicability of the equation and numbers supplied by Exhibit "A" and the subsequent letter. I here only determine the dose rate from a single detached fuel bundle based on their assumed accuracy and applicability to the whole core.

I declare under penalty of perjury that to the best of my knowledge and belief the foregoing is true and correct.

Executed on September 4,
1982, at Manhattan Beach,
California

Roger L. Kohn

Roger L. Kohn, Ph.D.

ill INSTITUT MAX VON LAUE - PAUL LANGEVIN

DOCKET NUMBER
PROPOSED RULE PR-50 (43)
(49FR 27769)

Le Directeur
No. direct: (76)48.71.00

USNRC

'84 SEP 10 P3:34

DOCKETING & SERVICE
BRANCH

The Secretary
US Nuclear Regulatory Commission
WASHINGTON DC 20555
USA

Attention: Docketing & Service Branch

Grenoble, le 28 August 1984

V/lettre du

Notre référence à rappeler :
BEFF/JMW

Dear Secretary,

I am writing in connection with the Nuclear Regulatory Commission's proposed rule to substitute low energy uranium fuel for highly enriched uranium fuel whenever possible.

The Institut Laue-Langevin, the world's leading centre for neutron research, depends entirely on achieving the highest possible neutron flux. The instruments are specially designed to make use of this high flux and many of the experiments carried out at the Institut are experiments which cannot be carried out at medium flux reactors. There is no question in our case that substitution of highly enriched fuel would be severely damaging to the goals of the Institut. Indeed it is unlikely that the Institut could continue in such circumstances.

The Institut, which has many collaborations with American laboratories, is well satisfied with the relations that we have had with the United States for the supply and reprocessing of fuel, and I hope we can continue with the existing arrangements, whatever changes follow for other reactor centres.

Yours faithfully,

B. E. F. Fender
Director, ILL

Acknowledged by card 9/11/84 DA

Suzanne E. Meek
F-23 Koshland Wy. • Santa Cruz, CA 95064

DOCKET NUMBER PR-50 (44)
PROPOSED RULE (49 FR 27769)

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington D.C.

Aug. 28, 1984

DOCKETED
USNRC

'84 SEP 10 P3:49

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Attn: Docketing & Service Branch,

Please do consider amending your regulations to limit the use of highly enriched uranium (HEU) fuel in domestic research and test reactors (non-power nuclear reactors)

The risks are too great that the HEU fuel could possibly fall into the wrong hands. Terrorist groups or nations intent on acquiring nuclear arms could possibly steal enough HEU from any of the unguarded 23 college campus universities. The theft of even one kilogram of highly enriched uranium could possibly be enough to produce a bomb.

Please consider using LEU instead of HEU.

Sincerely
Suzanne E. Meek

Acknowledged by card. 9/11/84

DOCKET NUMBER PR-50 (38)
PROPOSED RULE
(49 FR 27769)

12212 Coult Street
North Hollywood, CA 91605
August 28, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington D.C. 20555
Attention: Docketing & Service Branch

Re: NRC Proposal to Require Use of Low-Enriched Uranium Fuel in Non-Power Reactors

'84 SEP -5 P4:04

To The Secretary Of The Commission:

I strongly support the Nuclear Regulatory Commission's proposed rule to convert non-power reactors to use of low-enriched uranium fuel ("LEU"). I agree with the Commission's statement in its July 6, 1984 News Release that the new rule could reduce the risk of theft or diversion of highly enriched uranium ("HEU") and could influence foreign operators of non-power reactors to also convert to LEU. As physicist Theodore B. Taylor said last January in his testimony before the NRC, the presence of HEU in non-power reactors with very lax security is "highly undesirable and dangerous" and there are no research-related reasons which justify the continued use of HEU fuel in these reactors.

Because of this tremendous threat to U.S. security posed by the presence of HEU in non-power reactors, the Commission should require all such reactors to convert to LEU use at the earliest, physically possible date. I recognize that the conversion of all facilities could cost as much as $15 million and some facilities might have a "unique purpose" for utilizing HEU. However, in light of the security risks posed by non-power reactor HEU fuel usage, these and other factors such as reactor usage and availability of suitable LEU should not be permitted in anyway to slow down or interfere with the conversion process.

Sincerely,

Debora B. Gelberg

Debora B. Gelberg
Law Student
Northeastern University

[illegible] 8/30/84
pd

RICHARD G. SAXON. M.D.. INC.
16260 VENTURA BOULEVARD
ENCINO. CALIFORNIA 91436
789-0581

ORTHOPEDIC SURGERY

DOCKET NUMBER
PROPOSED RULE PR-50 (25)
(49FR 27769)

August 28, 1984

'84 AGO 30 P12:33

Secretary of the Commission
Nuclear Regulatory Commission
Washington, DC 20555

Attn: Docketing and Service Branch

Dear Sir:

I am very much in favor of your new proposal to convert thirty research reactors to low enriched fuel. The most probable cause of any future nuclear war is undoubtably that of an unstable leader in a minor country obtaining a nuclear weapon manufactured from stolen sources. Any effort to prevent nuclear weapons proliferation is mandatory. Any failure to do so will be irretrievable.

Although this change in the fuel will increase operating cost, it will be a small price to pay for our safety and peace of mind.

Sincerely,

Richard G. Saxon

Richard G. Saxon, M.D.
RGS/pw

Acknowledged by card. 9/4/84
pd

1500 N. Branciforte Ave.
Santa Cruz, CA. 95065
August 28, 1984

DOCKET NUMBER
PROPOSED RULE PR-50
(49FR 27769)

(26)

Docketing and Service Branch
Secretary of the Commission
U.S.N.R.C.
Washington, D.C. 20555

DOCKETED
USNRC
'84 AGO 30 P4:21
BRANCH

Dear people:

I am deeply concerned about the presence of highly enriched (weapons grade) uranium fuel in the thirty research reactors in the United States. This fuel must be tempting booty for terrorist organizations and nuclear-aspiring nations and represents a dangerous and unnecessary threat of nuclear proliferation. It is also a dangerous presence in our population centers, where these research facilities are located.

I urge you to adopt the HEU Conversion Rule 49 (Federal Register 27769) to convert these reactors to low-grade uranium fuel.

Thank you.

Mark A. Mathews

Acknowledged by card. 9/11/84 pd

PR-50
(49 FR 27769) (32)

SOUTHERN CALIFORNIA FEDERATION OF SCIENTISTS
3425 McLaughlin Avenue, Suite 209
Los Angeles, California 90066

August 28, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

'84 SEP -4 P4:25

Dear Mr. Secretary:

The Southern California Federation of Scientists supports the Nuclear Regulatory Commission's proposed rule which would restrict the use of highly enriched uranium(HEU) in U.S. research and test reactors (49 Federal Register 27769), with the following qualifying remarks.

The rule is intended to reduce the risk of theft or diversion of HEU by replacing it with LEU; to encourage similar conversion of research and test reactors by foreign reactor operators; and thereby to reduce the amount of HEU fuel in international use. In order to achieve these aims, the rule must be strictly applied and quickly implemented.

A "unique purpose" should not be sufficient basis for an exemption from the rule. The reactor function which requires HEU ought to be not only unique, but of vital significance to national security. We know of no such function which could not be performed using LEU.

Conversions should be carried out within one year of the date that the necessary LEU becomes available. Deferrals, like exemptions, should be granted only when justified by national security needs. Financial considerations, availability of shipping casks, or pattern of reactor usage obviously do not constitute such justification.

No license amendment should be required unless current safety margins are reduced by conversion to LEU. In such a circumstance, license amendment should be required. A "generic envelope of safety limits" should not be used to conceal a decrease in reactor safety.

Thank you for your consideration.

Sincerely,

Sheldon C.

Sheldon C. Plotkin, Ph.D.
Co-Chair

9/5/84
pd

GOVERNMENT OF THE STUDENT BODY
IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY
58 MEMORIAL UNION
AMES, IOWA 50011
PHONE 515-294-1585

President
MICHAEL REILLY

Vice President
MERRY MATHES

DOCKETED
USNRC

'84 SEP -4 P3:52

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)
(31)

August 29, 1984

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

RE: HEU Conversion Rule (49 Federal Register 27769)

My letter is to encourage the Nuclear Regulatory Commission to require that all nuclear research reactors convert from use of HEU to low enriched uranium.

This material poses a serious threat to the well being of everyone at Iowa State University. The possibility of this material falling into the hands of those who would use it for weapons purposes is even more frightening. We cannot afford to wait for this to happen.

We would like the Nuclear Regulatory Commission to take immediate steps toward implementing these changes. We are also encouraging the administration at our campus to support these changes.

Thank you for your consideration.

Sincerely,

Michael Reilly
GSB President

dlh

Acknowledged by card 9/5/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) ㊱

Wendy Schmelker
Box 1186
Ben Lomond, CA 95005
August 29, 1984

Attn: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir/Madam,

As a citizen concerned about nuclear proliferation and the threat of nuclear theft and diversion related to research reactors, I strongly support a strong, mandatory HEU conversion rule. The passage and strict enforcement of this rule would help to regain U.S. credibility on nuclear non-proliferation matters; but only if no extensions, loopholes, or delays were granted. LEU fuel is now available, and thus there should be no reason not to convert which out-weighs the importance of doing so, immediately, both in terms of international standing as well as our own domestic safety and security. Let's not wait for an "incident" to occur; take the initiative to protect the people and reputation of our nation: pass and enforce promptly the HEU fuel conversion rule---and don't gut it with drawn-out implementation schedules and exemptions and loopholes.

Thankyou for your consideration.

Sincerely,
Wendy Schmelker
Wendy Schmelker

Acknowledged by card 9/5/84
pd

DOCKET NUMBER PR-50 (34)
PROPOSED RULE
(49 FR 27769)

ASUCD
ASSOCIATED STUDENTS
364 Memorial Union • (916) 752-1990

August 29, 1984

'84 SEP -4 P5:32

Attn: Docketing & Service Branch
Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to support the conversion of highly enriched uranium reactors.

HEU, usable in atomic weapons, poses a threat to national and global security. We need not wait for this fuel to be stolen to begin the conversion process. As the undergraduate representitive to the U.C. Student Body Presidents Council from Davis I am especially concerned with reactors on Santa Barbara and Los Angeles U.C. campuses, but we should aim at converting all HEU reactors that can operate equally as well with LEU.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help discourage the use of HEU fuel worldwide.

Thank you for your consideration.

Sincerely,

Joseph Mele

Joseph Mele
ASUCD Vice President
UCD SBPC Representitive

Acknowledged by card 9/5/84
pd

University of California, Davis 95616

DOCKET NUMBER PR-50
PROPOSED RULE
(49 FR 27769) (40)

Mary A. Tsalis
151 Santa Dr.
Ben Lomond, CA 95005
August 29th, 1984

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to support conversion of all nuclear reactors which use highly enriched uranium.

It concerns me greatly that this fuel, if stolen, could be made into nuclear bombs thereby adding to the grave problem of nuclear proliferation. The financial cost of converting to low enriched fuel is insignificant when compared to the grave risk & far greater cost should highly enriched fuel be stolen.

I urge a prompt non-voluntary conversion of all research reactors to the (LEU) low enriched fuel.

Thank-You for your consideration.

Yours truly,

Mary A. Tsalis
Mary A. Tsalis

Acknowledged by card 9/10/84 pa

PR-50 (49 FR 27769) ㉙

University of Notre Dame
Notre Dame, Indiana 46556

Aerospace and Mechanical Engineering

Telephone 239-5430
Area Code 219

August 31, 1984

'84 SEP -4 A11:43

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Docketing and Service Branch

Dear Sir:

This letter is written to express my concerns, both as an individual and as Past-Chairman of the Education Division of the American Nuclear Society with regard to the proposed (Federal Register, Vol. 49, No. 131, pp. 27769-27772) change to 10CFR Part 50.

My concerns arise from the Commission's haste to draft and issue a rule with regard to conversion of University Research Reactors from HEU to LEU fuels without fully considering the impact of the proposed rule or alternative actions which may more effectively meet the concerns which gave rise to the proposed rule.

Commission policy, as set forth in NUREG-0885, I believe, calls for a systematic evaluation of risks and benefits associated with a proposed generic rulemaking. The proposed rule, in my view, warrants a more systematic look at the impacts and social costs of the proposed action and a more careful evaluation of possible alternative actions.

The cost-benefit analysis contained in the Regulatory Analysis supporting the HEU/LEU rulemaking has been described by some NRC staff as inadequate, an assessment with which I fully agree. Some other points which were raised with only casual and unsubstantiated discussion in staff presentations are:

1. The probable loss of several U.S. research reactors due to an inability to fund the expense of extended litigation provoked by the conversion to LEU. The social impact of such a loss could involve a reduction in the number of training facilities and programs available in the United States with a concomitant reduction in the number of students in those programs. (This at a time when NRC and INPO studies estimate a need for more than 5,000 trained people for replacement and upgrading of operating staffs in U.S. power reactors.) The resulting curtailment of both physical and medical research programs in the U.S. may accelerate the development of these capabilities offshore, a development which may not be in the national interest.

   The case of the UCLA reactor research reactor provides an example of what to expect in this regard. After lengthy relicensing hearings with no decision, and the specter of this HEU/LEU conversion before them, University authorities decided to close the reactor. It is my understanding that the Committee

9/5/84 pd

to Bridge the Gap, which intervened in opposition to the UCLA license, has pledged to challenge all university reactors applying for relicensing.

2. From a risk assessment point-of-view, a prudent national policy to limit the flow of highly enriched material would devote maximum effort and resources to those situations where the amounts of material involved are largest and the levels of shipping and handling are high. A qualitative ranking of HEU uses and users suggests that low-power research reactors are at the bottom of such a list, with medium-power university reactors next lowest. A near-term changeover from HEU to LEU fuel in small research reactors may indeed "set a good example". It will not, however, reduce the diversion risks from the much larger inventories and material flows associated with larger, non-university reactors. These risks, it appears, will continue for several years (possibly four or five), regardless of the timing required of domestic university reactors. This consideration indicates a need to reevaluate the pace (in some cases, the need) for conversion to LEU. It is important that these conversion efforts not divert the staff and resources of DOE, NRC, and the State Department from the much larger non-domestic risks.

3. One of the apparent motives for NRC action in this area is the rise in terrorist activity and the postulation of highly coordinated, internationally supported, terrorists with substantial resources. Terrorists might have as objectives any combination of five items:

   a. personnel casualties;

   b. facilities damage;

   c. dispersion of radioactive material;

   d. diversion of HEU fuel; and

   e. symbolic activities aimed at raising and manipulating public alarm.

   I suggest that the proposed conversion to LEU fuel does not address or significantly impact items a through d, and appears to enhance the attractiveness of item e.

4. A systematic risk evaluation of material diversion from small research reactors by a neutral, but well-informed, panel appears to me to be a necessary prelude to any rulemaking. A policy of

reducing the tonnage flows of HEU in international commerce appears prudent, since the amounts of material in some single shipments and single locations appear to be more than ample to make one or more nuclear explosive devices. The implication, however, that domestic research reactors present a comparable risk deserves a more careful evaluation. (Note that low power research reactors contain only a fraction of the amount of material required to make a plausible nuclear explosive.) The paper of Dr. E. L. Zebroski, "Relative Diversion Exposures of HEU: Relation to University Reactors", presented at the June 1984 meeting of the American Nuclear Society explores this question of relative risk in some detail.

5. It may be that the Commission has substantiated information on risk exposures which are not known to universities, and which provide a sufficiently compelling basis for the "as soon as technically practical" guideline provided to the staff for conversion to LEU fuel. If such compelling evidence exists (particularly since conversion does not actually address most of the risks), I believe it proper that the Commission and/or appropriate security agencies share this information with effected members of the university community (on a classified basis if necessary). If such compelling evidence does not exist, it is appropriate for the Commission and its staff to more carefully investigate the alternative actions and impacts noted above.

6. The $15 million expense, presumably to be funded by DOE, for HEU/LEU conversion envisioned in NUREG/CR-3666 will have no discernable educational benefit. The same amount used to upgrade obsolescent university laboratories would have a major impact on the quality of engineering education in this country. Absent the compelling evidence mentioned in 5 above, the Commission should not only consider whether the proposed measures are possible, but also whether they represent a reasonable use of scarce federal and university funds.

   In addition to the $15 million expense for physical conversion, it is simply impossible to estimate the legal expense of the associated relicensing, but it is likely to be of the same order of magnitude. Intervenor groups opposed to nuclear energy utilization in any form have demonstrated their ability to cause licensing proceedings to stretch on for years. This is an expense which universities are simply unable to meet.

I request that the Commission not accept the proposed HEU/LEU rule published for public comment. When all costs are weighed against the few benefits of the proposed rule there is no justification for its adoption.

Sincerely,

John W. Lucey
Associate Professor

JWL:slj

Commission of the European Communities
JOINT RESEARCH CENTRE

Petten Establishment

Postbus 2, 1755 ZG Petten, The Netherlands
Tel. (02246) 6442 - Telex 57211 REACP

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

42

AIR
MAIL

The Secretary of the Commission
U.S. Nuclear Regulatory Commission
WASHINGTON, DC 20555
USA

DOCKETED

'84 SEP 10 P3:52

Attention: Docketing and Service Branch

Petten, August 31, 1984
PvdH/npr-82.684

Gentlemen,

Federal Register, Vol. 49, No. 131
Proposed Rule "Limiting the Use of Highly Enriched
Uranium in Domestic Research and Test Reactors."

Enclosed comments do not refer to the Proposed Rule as such since that would be beyond my formal and professional competence.

I merely wish to express ideas about the possible impact of the Rule on the attitudes of European non-power reactor operators.

Please note that the enclosed notes reflect my personal ideas and do by no means commit the European Communities.

Sincerely,

v. der Hardt
P. von der HARDT
Head, HFR Division

ENCL.

9/11/84

Federal Register, 49, No 131, 27769-27772 (July 6, 1984)
Proposed NRC Rule
"Limiting the Use of Highly Enriched Uranium
in Domestic Research and Test Reactors" PvdH/npr-82.684

Personal Comments

A. There is full agreement on the basic necessity and principles of nuclear non-proliferation.

The recommendations of INFCE Working Group 8C have been taken seriously in Europe, and several countries operate government-funded programs for studying research and prototype reactor conversion to reduced enrichment fuel. A number of organisations have entered into collaboration agreements with the DOE RERTR Program. A whole core LEU conversion of a 70 MW test reactor has been demonstrated by the French CEA since several years.

B. The larger European test reactors have implemented physical security systems in accordance with IAEA recommendations. A specially designed high security vehicle is used for road transports of unirradiated HEU. Administrative and physical checks of HEU inventories and movements take place regularly by Euratom and IAEA inspectors.

C. Pressure on European research reactor operators to convert to low enriched fuel is exerted by US Government agencies during the review process of export license requests. Since 1983 the demands for HEU export licenses have to be supported by a questionnaire with details on the reactor's fuel cycle and on its operator's involvment in conversion studies, and by a conversion time schedule. The pressure exerted seems to vary from tough ("This was your last export license") to soft or non-existing.

D. The proposed rule specifically refers to non-US reactors and to the encouragement to conversion that should be achieved. It is limited, however, to medium and low power reactors of 5 MW maximum power (with the exception of MURR and NBSR). Large test reactors in National Laboratories are not concerned. The impact on overseas reactors would therefore be limited to installations below 5 MW which, as in the US, consume only a minor fraction of the total HEU in circulation.

E. There are moreover a number of questions to which no satisfactory answers are available to date:

1. fuel performance: Only LEU fuel up to 3 g U/cm^3 for low to medium power reactors has been sufficiently qualified. Another step forward is expected for 1985/86 with the whole core experiment in ORR on 4,8 g U/cm^3 silicide fuel. Higher density silicide fuel, required for high flux/high power reactors, will not be commercially qualified before 1987/88.

2. core physics: Reducing the enrichment from 93% to 20% implies, which ever the fuel type, adding ten or more kg of ^{238}U to the reactor core. Core physics studies have shown that this is feasible, with satisfactory reactivity development through core lifetime. On the other hand, there is marginal loss of fast and substantial loss of thermal neutron flux. A number of experimental applications of research reactors are hit by such development, and solutions need to be found to overcome this problem.

   As for cost analyses and licensing aspects, however, generic studies of core physics (and possibly, thermohydraulics) cannot supply the information needed by the individual reactor operator. Case-by-case analysis is required.

3. fuel cycle: US Government statements are missing on the following issues:

   a) swift handling of future LEU export licenses

   b) reprocessing of LEU fuel elements

   c) the price of reprocessing, and the residual fissile material credits

   d) guaranteed civil use by the US of the returned material.

4. cost: The two issues are conversion expenses and the increase of the annual fuel cycle cost.

Conversion expenses cover studies, calculations, fuel element design and testing, plant modifications, licensing, and possible losses on the last HEU elements. They are partially covered by Government-funded programs but estimations on their final amounts are not available.

Studies on annual LEU vs. HEU fuel cycle costs have recently been initiated. Although still hampered by uncertainties of reprocessing and fuel element manufacture cost, the following estimation is presently possible

Cost item	Estimated LEU vs. HEU fuel cycle cost increase /%/
Uranium mass in circulation	10
Reprocessing	0 to 20
Fuel element manufacture	10 to 40
Reactor power increase (compensating loss of neutron flux)	5 to 10
TOTAL	25 to 80 %

F. In conclusion, as far as the impact on European reactors is concerned, the following comments can be formulated:

1. In view of the remaining technical and economic uncertainties the statement "The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, ..." appears to be premature.

2. Large differences exist between different European research reactors in terms of their designs, modes of operation and utilization, and political environments. Case-by-case convertibility assessment is therefore required.

3. Although the ORR is implied through the planned whole core silicide fuel demonstration, other large DOE reactors are not concerned by the proposed rule. This weakens the case of demonstrating "good will" to the outside world.

62.

DOCKET NUMBER PROPOSED RULE PR-50 (39)
(49 FR 27769)

Sept 1, 1984

'84 SEP -5 P4:05

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
RE: HEU Conversion Rule
(49 Fed. Reg. 27769)

Dear Sir:

We are writing to support conversion of all nuclear reactors which use highly enriched uranium.

This atomic weapon material poses a threat to national and international security. The reactors must be converted now before the possibility of theft. The cost of this conversion is insignificant compared to the dangers.

Thank you for your consideration.

— Sincerely

Karla Smuts, [illegible]; David Shoop
P.O. Box 135
Pescadero, CA 94060

9/5/84
pd

Vol. 1

DOCKET NUMBER PR-50
PROPOSED RULE
(49 FR 27769) (41)

James Lewis
Coordinator
Educators for Social Responsibility
Chemistry NS II
University of California
Santa Cruz, CA 95064

DOCKETED
USNRC

'84 SEP -7 A11:33

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

September 2, 1984

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Sirs,

This letter is in response to proposed rule 10 CFR Part 50. Overall, I feel that the proposed regulation should strongly support the rapid conversion from unnecessary HEU use in research reactors. Some of the provisions seem sufficiently vague that some doubt may be left about what NRC policy really is in this matter.

Specifically I feel that financial considerations should not be a factor in conversion to LEU use. Until the U. S. is in compliance domestically with NRC policy, any money spent encouraging international restraint will be wasted. It seems to me that the role of the NRC is to implement a consistent nuclear policy **in the face of reluctance by those who might be inconvenienced.**

Along these lines I suggest that rather than allow exceptions for "specific experiments" and thus leaving a loophole, staff should encourage experiments to be moved to appropriate facilities as is usual in high energy physics or not uncommon even in my own field of chemistry. In general, this regulation needs to be tightened up if it is to be regulation at all.

Sincerely,

James Lewis

James Lewis Ph.D.
Coordinator
Educators for Social Responsibility
Santa Cruz Chapter

Acknowledged by card 9/10/84 pk

64

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

D.K. HARLING
Director

138 Albany Street Cambridge, Mass. 02139
(617) 253-

L. CLARK, JR.
Director of Reactor Operations

September 5, 1984

The Honorable Nunzio J. Palladino, Chairman
United States Nuclear Regulatory Commission
Washington, D.C. 20555

9/11...To EDO for Appropriate Action..Cpy to:RF..
84-0903

Subject: Improved Security for Non-Power Reactors

Dear Chairman Palladino:

Massachusetts Institute of Technology desires to comment on information regarding physical security at non-power reactors (NPR's) presented by the Nuclear Regulatory Commission staff at the annual meeting of the National Organization of Test, Research and Training Reactors (TRTR) in August 1984. The information presented by the staff relates to potential requirements for improved physical security capabilities for NPR's, specifically those reactors possessing high enriched uranium (HEU) subject to Category II requirements (10 CFR 73.67(d)).

The information presented at the meeting consisted of "Proposed Improved Capabilities" and listed the following:

- Impede unauthorized removal of SSNM
- Detect both unauthorized penetrations and activities
- Protect against theft by a single insider
- Provide tamper-indication on detection systems
- Detect attempts to prevent assessment of alarms
- Improve communications capability to LLEA
- Arrange for at least one, armed LLEA respondant
- Reduce fresh HEU fuel inventory as low as practicable

MIT considers that the proposed improved capabilities constitute acceptable security requirements, if they are reasonably interpreted, reasonably applied, and particularly if they are adopted as an alternative to the potential requirement for the conversion of high enrichment uranium (HEU) fuel to low enrichment uranium (LEU) fuel. However, it is believed that they represent only marginal improvement over MIT's present security plan, which meets the requirements of 10 CFR 73.67(d), which has been approved by NRC, and which is considered fully adequate to limit the diversion risk to acceptable levels. This is especially true because MIT maintains its inventory of unirradiated fuel at very much less then the maximum of 5 Kg permissible under 10 CFR 73.67(d) except just prior to refueling; theft of fuel by a single insider, alone or with external help, is not feasible; and the dose rate from its irradiated fuel exceeds the self-protecting 100 rem/hour at one meter by two orders of magnitude or more.

With regard to the above proposed improved capabilities, it is not possible to be specific until the precise wording of a proposed rule is published. Until such time, MIT's comments must be considered tentative and, in any event, they apply to MIT only. We cannot speak with regard to the impact of such new rules on other reactors, since we necessarily lack knowledge regarding their security plans, but it appears that the rules would not seriously affect MIT if, as mentioned above, they are reasonably interpreted and applied.

Sincerely,

John a Bernard Jr

John A. Bernard, Jr.
Reactor Superintendent

Lincoln Clark Jr.

Lincoln Clark, Jr.
Director of Reactor Operations

DOCKET NUMBER PR-50 45
PROPOSED RULE
(49FR 27769)

6400 Georgetown Pike
McLean, Virginia 22101

'84 SEP 12 P2:06

September 8, 1984

Secretary of The Commission
U.S. Nuclear Regulatory Commissiom
Washington, D.C. 20555

Dear Sir:

I understand that the Nuclear Regulatory Commission is considering a proposed Regulation that would require the conversion of all U.S. research reactors from the use of highly enriched Uranium (HEU) to non-weapons grade material. I strongly support this proposed regulation and urge its issuance.

I am enclosing a Declaration that I made to the Atomic Safety and Licensing Board in 1982 in the case of the University of California at Los Angeles reactor. In addition to the brief description of my professional qualifications appended to the enclosed Declaration, I was a Member of the USAEC Committee on Nuclear Safeguards from 1970 to 1972.

I still support the position stated in that Declaration. The United States must set the standards and abide by them itself if it is to persuade other nations to forego the unecessary use of HEU, which can be used directly in nuclear weapons. Today with the increased dangers of nuclear terrorism, every possible step must be taken to reduce the risks that weapons grade materials will fall into irresponsible hands.

I would appreciate it if my views were taken into consideration as the Commission addresses the proposed regulation.

Sincerely yours,

Herbert Scoville, Jr.

Acknowledged by card 9/13/84 pt

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of THE REGENTS OF THE UNIVERSITY OF CALIFORNIA (UCLA Research Reactor)	Docket No. 50-142 OL (Proposed Renewal of Facility License)

DECLARATION OF DR. HERBERT SCOVILLE

I, Herbert Scoville, declare as follows:

1. I am presently President of the Arms Control Association. Prior to that time I was Assistant Director of the U.S. Arms Control and Disarmament Agency; before that I was Deputy Director of the Central Intelligence Agency for research. From 1948 to 1955 I was employed by the Armed Forces Special Weapons Project (now the Defense Nuclear Agency) of the Defense Department, studying nuclear weapons effects. A more detailed description of my professional qualifications is attached.

2. It is my understanding that UCLA has requested from the NRC a license for up to 4999 grams of Uranium-235 at 93% enrichment, recently amended from a request for 9400 grams.

3. It is my professional opinion that, absent extremely compelling reasons to the contrary, the facility should instead employ low-enriched fuel, i.e. special nuclear material that cannot be used directly in nuclear weapons. My reasons are as follows.

4. 93% enriched uranium is weapons-grade. In other words, it can be used directly in nuclear weapons without further enrichment. As such, it is extremely sensitive material which needs to be carefully safeguarded. More particularly, it should only be used where absolutely necessary.

5. The move to cut down the amount of HEU at the research reactor at UCLA can have very salutary international effects as well as ones locally. It is important from a U.S. policy standpoint to make as difficult as possible the acquisition of material such as HEU that can be easily fabricated into a bomb.

6. However, we cannot hope to have one standard in the U.S. for availability of HEU and for safeguards on its use and a different standard for other countries. The precedent set at UCLA will be useful in dealing with other countries such as India or Brazil as they seek HEU for their research reactors.

7. A recent example of this problem arose in Iraq. The French were supplying Iraq with a research reactor using HEU. We tried to persuade the French to provide only lower enriched material but the Iraqi government refused to accept this. When the HEU became available in Baghdad the Israelis felt it necessary to carry out a preemptive bombing raid to destroy this reactor. While I think such a violent reaction was very ill-advised, it nevertheless demonstrates the dangers of having large amounts of HEU available in locations where it might be seized and converted to a weapons program. It is perhaps more likely that a nuclear war will start with a bomb being used by a small country or terrorist organization in the Middle East than that the Soviet Union and the United States will start a nuclear war with their thousands of warheads. Therefore the control of HEU is very important, and the standards set in the UCLA case should be useful in dealing with such a problem in the future.

8. For many research reactors it is no longer necessary to have HEU with 93% enrichment; 20% may be quite satisfactory, and this cannot be used for weapons. Therefore, a second step at UCLA, in which the reactor would be converted to use only 20% material, would be very important. It is hoped that having taken the first step of reducing its inventory of 93% material, it will now move on to this conversion to 20% enriched fuel.

I, Herbert Scoville, swear under penalty of perjury that the foregoing is true and correct to the best of my knowledge and belief.

Executed on October 17, 1982,
at Los Angeles, California

Herbert Scoville, Ph.D.

PROFESSIONAL QUALIFICATIONS OF DR. HERBERT SCOVILLE

I am presently President of the Arms Control Association, which I co-founded in 1970.

From 1963-1969 I was Assistant Director of the United States Arms Control and Disarmament Agency. Prior to that I was Deputy Director for Research (Science and Technology) of the Central Intelligence Agency.

From 1948 to 1955 I was Technical Director of the Armed Forces Special Weapons Project (now the Defense Nuclear Agency) of the Defense Department, studying nuclear weapons effects.

From 1946 to 1948 I was Senior Scientist at Los Alamos, studying weapons effects for the Atomic Energy Commission.

I received my B.S. from Yale in 1937 and my Ph.D. in physical chemistry from the University of Rochester in 1942.

PR-50 (46)
(49 FR 27769)

414 Rose Avenue--Box 147
Aromas, CA USA 95004
10 September, 1984
'84 SEP 14 P5:46

Secretary to the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Section
Regarding: Proposed Rule to Reduce Use of Highly Enriched Uranium (49 FR 27769)

To the Commission:

I understand that the Nuclear Regulatory Commission is considering a proposal to require university research reactors to convert to non-weapons-grade fuel. I applaud the proposed rule and urge that it be rapidly and strictly implemented. The risks of nuclear weapons proliferation and nuclear terrorism are so grave, no delays or exceptions should be permitted.

The purpose of the rule is two-fold: to reduce the risk of weapons-grade material being stolen from largely unprotected U.S. campuses, and to make possible our foreign policy goal of reducing or eliminating the use of Highly Enriched Uranium abroad. If we fail to convert, or delay conversion by a decade or more, as some propose, we undercut both goals. The longer bomb material remains on campus, the greater the risk of theft or diversion, and the more vulnerable these campus reactors are as serious security risks. If the U.S. is perceived as dragging its feet in this matter, then foreign nations--where security is even less strict than it is here--will delay as well.

I have heard that the primary objections to this regulation are economic. These arguments seem to me to be fatuous. The $14 million cost of conversion--the figure being handied about--is peanuts compared to what it would cost if terrorists or others somehow got hold of bomb-grade fuel. As you well know, several popular publications have printed directions for bomb manufacture. The only hope of preventing a disaster is to keep enriched fuel out of the hands of those who might misuse it. Were the universities required to adequately protect this material, the financial costs would be far greater than those being considered for conversion. And such security measures would be inconsistent with the atmosphere of universities.

I understand, moreover, that Congress has already appropriated $2 million for the coming fiscal year to start the conversion process. There is apparently a strong commitment to providing the remaining funds over the next few years as the conversions take place. Even if a few marginal reactors chose to shut down rather than convert, the loss of such marginal programs or the cost to a facility of contributing to the conversion pales in comparison to the costs and risks associated with weapons-grade materials.

Conversion is essential; it must be mandatory, with no exceptions whatsoever. Implementation schedules can and should be rapid. Operating schedules of reactors, cask availability and the like should have little or no ability to delay conversion. While it might make sense to schedule conversions geographically--so as not to require casks to be shipped to the West Coast for one conversion, then the East Coast for another, then back to the

Acknowledged by card. 9/18/84 pd

West, and so on--this should speed up conversion, not delay it.

This said, two parts of the proposed regulation worry me.

First (ref: para. D-2), licensees are given one year to come up with a letter telling the NRC how long it plans to take to carry out the conversion. This is absurd for such an important matter, and threatens to gut the rule entirely. What with extensions, outlandishly delayed schedules, and so on--tactics typical of reactor operators, from what I have observed--this project could take ten years to carry out. That may be far too late.

Second (ref: Fed. Reg. 7/6/84 p 27770 col 3), the proposal threatens to eliminate the public's review of the conversion process. If there is no diminution is safety margins by conversion--and my understanding is that this is the case with all these conversions--then there should be no problem. If there is a diminution in safety margins, however, the public's right to raise its concerns should be maintained. In this regard, the rule that if the licensee can show conversion will fall within "envelopes" of safety margin (to be established by the NRC) no review is required, is inadequate. The standard should be that conversion should not reduce existing safety margins. This seems to me both straightforward and easy to enforce.

(I am particularly concerned that reactor operators might attempt to raise power levels or reactivity limits at the same time they convert, in order to shield these changes from public inquiry. This should not be permitted.)

In summary, I support mandatory conversion of research reactors to non-weapons-grade fuel. This requirement should be without exceptions or loopholes, and implementation should be expeditious. I would suggest, in fact, that conversion be completed within 18 months from the time the appropriate fuel for the reactor becomes available. Most U.S. reactors under NRC jurisdiction should be converted to low-enriched uranium by 1990, with only a few still to be converted during the next couple of years thereafter.

No delays, no exceptions, no loopholes--the risks of theft or diversion of weapons-grade uranium are too great, and our interest in eliminating HEU use abroad too profound, for anything less to be required.

Sincerely,

James Spickard, PhD.

DOCKET NUMBER PR-50
PROPOSED RULE
(49 FR 27769) (51)

'84 SEP 18 A11:23

September 12, 1984

Ms. Corey Dzitzer
919 18th Street B
Santa Monica, CA 90403

Attn: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir;

I urge you to support conversion of all nuclear reactors which use highly enriched uranium.

HEU is weapons-grade and could be used, if stolen or diverted, to make an atomic bomb. LEU could not. Why pose a significant threat to national and international security? The financial cost of converting to non-weapons-grade fuel is insignificant compared to the potential costs of this threat.

The conversion should be carried out as soon as possible. Many successful conversions have already taken place such as at the University of Maryland's campus reactor. Furthermore, no reactors should be exempted from the rule, which is needed to enhance national and international security.

Thank you for your consideration.

Sincerely,
Corey Dzitzer
Ms. Corey Dzitzer

Acknowledged by card 9/18/84

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(60)

Associated Students of the University of California
DAVIS • BERKELEY • SAN FRANCISCO • SANTA CRUZ • IRVINE • RIVERSIDE • LOS ANGELES • SANTA BARBARA • SAN DIEGO

STUDENT BODY PRESIDENTS' COUNCIL

'84 SEP 24 P2:24

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

September 12, 1984

✓Chairman Palladino
Commissioner Asselstine
Commissioner Roberts
Commissioner Bernthal
Commissioner Zech
U.S. Nuclear Commission
Washington, D.C. 20555

Dear Commissioners:

Due to the unique proliferation hazards involved, you have recently issued a proposed regulation to convert U.S. nuclear research reactors from the use of weapons-grade (highly enriched) uranium. The Congress has appropriated $2 million for the first year to being the conversions.

The Student Body Presidents' Council of the University of California, representing 140,000 students on nine campuses, strongly supports conversion of all research reactors to non-bomb-grade uranium. We, therefore, applaud your proposed action in this regard and urge that it go forward expeditiously, without diminishing its intent of enhancing national and international security.

Enclosed, please find the SBPC resolution and our comments on the proposed rule as published in the Federal Register.

We urge your continuing attention to this important matter.

Sincerely,

Kayleen S. Kott

Kayleen S. Kott
Chair, Student Body Presidents' Council
359 Memorial Union
University of California
Davis, CA 95616

cc, Representatives Udall, Markey, Ottinger, Brown, Levine, Beilenson
Senators Hatfield, Cranston, Wilson

Enclosures

KSK:jeb

Acknowledged by card 9/25/84 pd

Associated Students of the University of California

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STUDENT BODY PRESIDENTS' COUNCIL

RESOLUTION

Supporting the Proposed Rule by the Nuclear Regulatory Commission on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

WHEREAS, 31 non-power nuclear reactors are licensed in the United States to use highly enriched uranium (HEU)- 25 are owned by universities including one at UCLA and one at UC Santa Barbara, 5 are owned by private corporations and 1 is owned by the U.S. government; and

WHEREAS, highly enriched uranium can be used without further significant processing and without extensive expertise to build nuclear weapons; and

WHEREAS, the security level at these facilities especially at those on university campuses are not sufficient to even moderately protect from a threat of theft; and

WHEREAS, the threat of terrorism is rapidly escalating world-wide and HEU could sell for over $100,000 per kilogram on the black market; and

WHEREAS, the United States government has spoken out around the world for the reduction of HEU, while at the same time the U.S. exports about 600 kilograms annually (the most in the world) and has not made an effort to limit the almost 500 kilograms of HEU within the U.S.; and

WHEREAS, the reduction of HEU within the U.S. may provide an example and incentive for other nations to emulate thus reducing the danger of international terrorism; and

WHEREAS, the low enriched uranium (LEU) fuels can be used without significant reduction in performance or research potential; now, therefore, be it

RESOLVED, that the Student Body Presidents' Council supports immediate conversion from HEU to LEU internationally and especially within the United States and that the rule must allow no exemptions if it is to accomplish its goal of enhancing national and international security.

8/18/84
KJG

Associated Students of the University of California

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STUDENT BODY PRESIDENTS' COUNCIL

August 29, 1984

Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

The Student Body Presidents' Council of the University of California, representing 140,000 students on nine campuses, strongly supports the proposed regulation to require conversion of all non-power reactors from highly enriched uranium (HEU) to the safer low enriched uranium (LEU). Enclosed, please find a copy of an SBPC resolution (8/18/84) supporting immediate conversion allowing no exemptions and thus enhancing national and international security.

The SBPC does not understand the NRC's preoccupation with the cost of conversion. We understand that financial considerations are important in determining the availability of LEU fuel (which for many facilities is free or relatively inexpensive due to oversupply at similar facilities) and that the scheduling of conversion does involve some financial considerations. However, it does not seem appropriate that the NRC concern itself with the "economics of conversion" as much as it should serve the public by assuring both public health and safety. If the NRC passes stringent regulations, the federal government will be encouraged to provide funding such as the Department of Energy has shown with $2 million to begin conversion in the first year. The cost of conversion, no matter who pays, is minimal compared to the cost of theft or accident at these research reactors. The cost of improving security at these research reactors to adequately protect this valuable and vulnerable material must also be considered.

The time frame proposed by the NRC is of concern to the students of California. According to the proposed rule, a licensee would not even be required to submit a proposed schedule for conversion for 12 months after passage of this rule. We believe one year is too long to wait to begin actual conversion. Furthermore, this regulation does not establish a date by which licensees must complete conversion. The scheduling of shipping casks should not affect the time frame since transportation time even across country could be not more than a few weeks. Also, conversion dates should not be affected by federal funding since the individual licensees have a responsibility to assure that their reactors comply to safety regulations.

The idea of "generic envelopes of safety limits for the several types of non-power reactors" is not acceptable to SBPC, although we do see the need for generic safety analysis for fuels. Licensees should not be required to merely submit to a set of vague generic rules, but rather be required to prove conversion has created no reduction in safety. If there are any questions as to the safety of the reactors due to conversion the public should be allowed to address these questions in a public hearing. The right to public hearing on safety issues is guaranteed by the Atomic Energy Act, and should not be forfeited in this regulatio or any regulation. Also, licensees should be required to conduct an environmental impact statement for any questions of safety or health. This statement like the "analysis showing that...normal operating and postulated accident conditions... fall within the limits" must be carefully checked by the NRC and be available for public inspection.

The possibility for exemptions seems overly lenient in this regulation. Reactors with a "unique purpose" could be exempt from conversion which could diminish the intent of the regulation which is to enhance national and international security. The regulation states reactors with "a special experiment or program" would be a candidate for exemption. One experiment should not overturn this needed regulation. Those research projects based on neutron flux levels or spectra are attainable with LEU fuels, as well as HEU fuels, with only slight modifications.

The NRC is encouraged to require MEU (medium enriched uranium) as close to 20 in those very rare cases where LEU, below 20%, is not possible. However, in almos all domestic research reactors, conversion below 20% is possible at this time. Fo this reason, the "continued success of the DOE funded RERTR program," although desirable, is not crucial to the success of HEU conversion.

In summary, the SBPC makes the following recommendations:

> The NRC base its decision for conversion of non-power reactors on the safety and health of the public and not on economic considerations.
>
> The time frame to submit a schedule for conversion be shortened and that the NRC set a date for complete conversion of reactors.
>
> There be no generic envelopes of safety limits, but rather licensees be required to prove no reduction in safety has been created by conversion.
>
> The public retain the right to public hearing on any questions of public safety.
>
> No exemptions be granted for domestic conversion.

Sincerely,

Kayleen S. Kott

Kayleen S. Kott
Chair, Student Body Presidents' Council
359 Memorial Union
University of California
Davis, CA 95616

KSK:jeb

Enclosure

[illegible]-50 (47)
(49FR 27769)

9/3/84
802 S. PLYMOUTH
LOS ANGELES, CA
90

ATTN.: DOCKETING & SERVICE BRANCH
SECRETARY OF THE COMMISSION
U.S. NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

RE: 'HEU' CONVERSION RULE (49 FEDERAL REGISTER 27769)

TO WHOM IT MAY CONCERN:

I am writing to express my support for the conversion of all nuclear reactors from highly-enriched uranium (HEU) fuel to low enriched uranium fuel (LEU). HEU fuel, to my understanding, is weapons-grade, and therefore the very real threat of theft of this material will exist so long as it is in use, posing a great danger to national ~~as~~ as well as global security. I believe that these conversions should be carried out as soon as possible, that no reactors should be exempted from this proposal, and further, that in order to be truly effective, these conversions should be non-voluntary and properly implemented.

Thank you for your attention in this matter.

Sincerely,
Francis Pinto

Acknowledged by card 9/10/84 pd.

(FRANCIS PINTO
U.S. CITIZEN)

OLIVIA DIAZ, M.S.

CERTIFIED REHABILITATION COUNSELOR
TELEPHONE (213) 681-2282

550 EAST CALIFORNIA PASADENA, CALIFORNIA 91106

PROPOSED RULE PR-50 (48)
(49FR 27769)

'84 SEP 17 P4:47

September 14, 1984

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

I have just learned that it is possible to convert HEU, which could be used to make atamonic weapons, to LEU, which could not. If the technology to do that exists and is feasible for use, why isn't it being put into effect immediately?

Theft of HEU to be used clandestinely to make atomic weapons is such a real possibility that everything should be done to prevent its possibility. I understand the cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

America must take seriously the threat of nuclear proliferation. By making this conversion mandatory, we can send a clear message to the world that we are doing what we can to make the world a little safer from irresponsible use of nuclear weapons.

Please move to make these conversions mandatory and do it immediately.

Sincerely,

Olivia Diaz

Olivia Diaz, M.S.

OD:s

Acknowledged by card.......9/18/84 pd

[illegible]-50 ㊾
(49 FR 27769)

'84 SEP 17 P4:47

September 14, 1984

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

But in order to be effective, it must be non-voluntary and it must be promptly implemented.

Thank you for your consideration.

Sincerely,

Joan M. Schiessl
5511 W. Olympic Blvd. - Apt. 7
Los Angeles, CA 90036

Acknowledged by card 9/18/84 pd

September 11, 1984

PROPOSED RULE PR-50 (50)
(49FR 27769)

US Nuclear Regulatory Commission
Secretary of the Commission
→ Docketing & Service Branch
Washington, D.C. 20555

'84 SEP 17 P.

Re HEU Conversion Rule (49 Federal Register 27769.)

Dear Mr. Secretary,

I write today to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

It frightens me to imagine this material (HEU) being stolen and used in an atomic weapon What a costly situation!

Please know that since low enriched uranium is available now, I see no reason for delay.

Thank you very much for inviting this consideration.

Sincerely,

Jean Watkins
US Citizen
12462 Beatrice St.
Los Angeles, CA 90066

Acknowledged by card 9/18/84 pL

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) (52)

9/14/84

Attn. Docketing + Service Branch
Secretary of the Commission
U.S Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 2776

Dear Sir:

I oppose the construction, lisencing and continual use of nuclear power plants because of the incredible danger to the environment and all living organisms. I would love to see all plants shut down and begin decommissioning.

But since this is quite unlikely to happen at the present time, I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

Because this material can be used in an atomic weapon, it poses an unnecessary threat to international and national security. We must deal with prevention! We should not wait for this fuel to be stolen and then implimend a change; we must convert these reactors now. Money should not be a factor influencing this proposal. The financial cost of conversion is insignificant compared to the potential costs involved

Acknowledged by card 9/18/84

if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapon grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide. In order to be effective, it must be non-voluntary and it must be promptly implemented.

While I have your attention I would like to say I strongly oppose the lisencing of the Diablo Canyon Nuclear Power Plant. We need to look past the financial cost and concentrate ~~of~~ on the biological cost of living things.

Thank you for your consideration

Sincerely

Kimberly Thompson

Kimberly Thompson
Thoreau Hall
550 Oxford Cir.
Davis CA, 95616

DOCKET NUMBER PROPOSED RULE PR-50
(49 FR 27769) (53) Vol. 1

SEP 18

9-14-84

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

But in order to be effective, it must be non-voluntary and it must be promptly implemented.

Thank you for your consideration.

Sincerely, etc.

Jordan Good
12440 Landale St.
Studio City, Ca. 91604

Acknowledged by card. 9/18/84 pd

PR-50 (59)
(49 FR 27769)

'84 SEP 24 P2

OFFICE DOCKE

September 17, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, DC 20555

Att: Docketing & Service Branch

Gentlemen:

I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to nation and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the United States takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

However, in order to be effect, it must be non-voluntary and it must be promptly implemented.

Very truly yours,

Hazel Berger

Hazel Berger
1800 Camden Ave., #207
Los Angeles, CA 90025

Acknowledged by card 9/25/84 pa

PR-50 (62)
(49 FR 27769)

JACK HEIDELBERG
11728 Wilshire Blvd. B-909
Los Angeles, CA 90025

'84 SEP 27 A11 :40

September 17, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, DC 20555

Att: Docketing & Service Branch

Gentlemen:

I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to nation and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the United States takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

However, in order to be effective, it must be non-voluntary and it must be promptly implemented.

Very truly yours,

Jack Heidelberg

Acknowledged by card. 10/3/84
pd

DOCKET NUMBER PR-50 (61)
PROPOSED RULE (49 FR 27769)

DOCKETED USNRC

'84 SEP 25 P12:48

DOCKETING & SERVICE BRANCH

September 17, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, DC 20555

Att: Docketing & Service Branch

Gentlemen:

I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to nation and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the United States takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

However, in order to be effective, it must be non-voluntary and it must be promptly implemented.

Very truly yours,

Minna Kaye

MINNA KAYE

310 S. Sherbourne Dr.-#106
Los Angeles, Ca. 90048

Acknowledged by card 9/25/84 pd

78

DOCKET NUMBER PR-50 (54)
PROPOSED RULE (49 FR 27769)

'84 SEP 19 A11:59

ATTN: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir

I wish to support the conversion of all nuclear reactors which use highly enriched uranium. As you know, this material can be used as fuel in atomic weapons and hence, poses a threat to national and international security. A mandatory conversion from HEU to LEU should begin as soon as possible.

The conversion of these reacters and removal of the weapons-grade fuel would be a signal that the United States is seriously concerned about the problems of nuclear weapons proliferation

Thank you for your consideration.

Michael T. Maw
4279 Bakman Ave
North Hollywood, Calif

Acknowledged by card 9/20/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50 (57)
(49FR 27769)

LAWRENCE WALLIN
8501 Ridpath Drive
Los Angeles, California 90046
(213) 654-0052

DOCKETED
USNRC

'84 SEP 24 P1:14

DOCKETING & SERVICE
BRANCH

Sept. 19, 1984

Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC. 20555

Dear Sir,

I support conversion of all nuclear reactors which use weapons grade nuclear matterials. By changing the current law (49 Federal Register 27769) we can significatly reduce the ~~th~~ chances of terrorists getting their hands on these supper toxic, dangerous matterials.

A small price to pay for a big increase of our security.

Sincerely,

Lawrence Wallin

Acknowledged by card 9/25/84 pd

80

DOCKET NUMBER
PROPOSED RULE PR-50 (58)
(49 FR 27769)

DOCKETED
USNRC

Bettine Wallin
8501 Ridpath Dr. • Los Angeles, California 90046 • (213) 654-0052

'84 SEP 24 P1:14

Sept. 20, 1984

DOCKETING & SERVICE
BRANCH

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulary Commission
Washington D.C. 20555

Dear Sirs: re: HEU Conversion rule
49 Federal Register 2776

I urge you to support the change in regulations away from weapons grade uranium in University reactors where they are more susceptible to theft. We need to seriously stop the chance of proliferation.

Sincerely
Bettine K. Wallin

Acknowledged by card 9/25/84 pa

DOCKET NUMBER PR-50 (56)
PROPOSED RULE
(49 FR 27769)

9-20-84

DOCKETED
USNRC

'84 SEP 24 P1:06

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Sirs:

We support your plan for the HEU Conversion.

I am referring to the plan to go from HEU to LEU. fuel.

The idea that a dangerous substance could be stolen or diverted (HEU) to make an atomic bomb is devastating.

The already endangered planet can afford more dangers.

Sincerely
M & M Holland
9019 Wonderland Park
LA Ca 90046

Acknowledged by card. 9/25/84
pd

DOCKET NUMBER
PROPOSED RULE PR-50 (65)
(49FR 27769)

Kimberley Shotwell
1917 Carzino Court
Concord, California,94521

DOCKETED
USNRC

'84 OCT -5 P1:33

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Attn: Docketing & Service Branch
Secretary of the Commission
U.S Nuclear Regulatory Commission
Washington, D.C. 20555

September 26, 1984

Dear Sir:

I am writing to show my support of the conversion of all nuclear reactors which use highly enriched uranium (HEU).

HEU, which can be used in the creation of an atomic weapon, presents an unwanted and unnecessary threat to security, both nationally and internationally This fuel can be easily stolen. It must be converted now. Even though there is argument over the cost of conversion, it is insignificant to the potential costs involved if a successful theft occurred.

Conversion of these reactors and removal of the weapons-grade fuel will be proof to the other countries in our world that the U.S. takes the problems of nuclear proliferation very seriously. The use of HEU fuel worldwide would be discouraged through this proposal.

Of course, in order to be totally effective, it must be non-voluntary and it must be done now and not in five or ten years.

Thank you for your consideration.

Sincerely,

Kimberley Shotwell

Kimberley Shotwell

Acknowledged by card 10/9/84

83

ASSOCIATED STUDENTS
University of California at Santa Barbara
University Center, Room 3177
Santa Barbara, California 93106

ASUCSB

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO • SANTA BARBARA • SANTA CRUZ

'84 SEP 28 P2:52

DOCKETING & SERVICE
BRANCH

DOCKET NUMBER PR-50 (63)
PROPOSED RULE
(49 FR 27769)

Attn: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to support conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

But in order to be effective, it must be non-voluntary and it must be promptly implemented.

Thank you for your consideration.

Sincerely,

Jim

James H. Hickman, Jr.
External Vice-President
Associated Students

Acknowledged by card. 10/3/84 pk

84

DOCKET NUMBER
PROPOSED RULE PR-50 (64)
(49 FR 27769)

DOCKETED
USNRC

'84 OCT -4 P3:40

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Donna Lomp
212 Hesperus Av.
Magnolia, Ma. 019

Nuclear Reglatory Commission
Washington D.C.

To the Secretary of the Commission:

I support the proposal which would require nuclear research reactors to convert from highly enriched uranium (HEU) to low enriched uranium (LEU) fuel.

The conversions should be carried out as soon as possible and no reactors should be exempted from the proposal!

The risk of terrorist attacks is too great + be carless with HEU.

Thank you.

Sincerely,
Donna V. Lomp

Acknowledged by card. 10/9/84
pd

GEORGE E. BROWN, JR.
2256 HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
(202) 225-6161

COMMITTEES:
AGRICULTURE
CHAIRMAN, SUBCOMMITTEE ON
DEPARTMENT OPERATIONS, RESEARCH
AND FOREIGN AGRICULTURE

SCIENCE AND TECHNOLOGY

TECHNOLOGY ASSESSMENT BOARD

Congress of the United States
House of Representatives
Washington, D.C. 20515

36TH DISTRICT OF
CALIFORNIA

DISTRICT OFFICES:
■ 657 LACADENA DRIVE
COLTON, CALIFORNIA 92324
(714) 825-2472

☐ 3600 LIME STREET, SUITE 116
P.O. BOX 71
RIVERSIDE, CALIFORNIA 92502
(714) 686-8863

☐ ONTARIO, CALIFORNIA
(714) 984-1706

'84 OCT 15 A10:50

OFFI
DOCI

October 4, 1984

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(69)

Docketing and Service Branch
Office of the Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: NRC Proposal to reduce and/or eliminate use of
highly enriched uranium (HEU) in University research.

Dear Commission Members:

I am writing to support the proposal by N.R.C. to reduce and, if possible, eliminate the use of highly enriched uranium (HEU) in university research, and replace it with low enriched uranium. I do so in the interest of national security, safety, and in demonstrating the United State's commitment to non-proliferation of nuclear weapons.

Based upon my review of testimony made by Dr. Theodore B. Taylor before the Commission this issue, and my own legislative efforts to reduce the threat of nuclear weapons to our society, and to the earth as a whole, I believe I can whole heartedly endorse such a move to eliminate weapons grade fuel from research facilities engaged primarily in non-defense work. Dr. Taylor makes a sensible and knowledgeable case for replacing 93% HEU with perhaps 20% HEU or even 48% HEU at the colleges and universities presently authorized to store and maintain kilogram or more guantities of such fuel, and I will not go into detail on the adequacy of low enriched uranium as a substitute for HEU in university research projects; thus has already been done effectively elsewhere. I will, however, go on to say that any potential drawbacks in research, which would appear to be minimal, would be more than offset by the greater safety and security afforded our nuclear research institutions. Furthermore, despite the estimated $15 million cost of replacing HEU with low enriched uranium regardless by whom such cost's borne, it is more than offset by the potential for damage and lives lost by the threat of nuclear extortion which presently exists, but would be virtually eliminated should the NRC proposal be accomplished. Even the expense for providing greater security for institutions requiring use of HEU is justified if it can serve to prevent nuclear terrorism on any scale.

Finally, I would hail the move by the NRC as a rational move toward a rational control of nuclear weapons proliferation; long overdue, but worthy nonetheless. I have strived, during my years in Congress to do my part to reduce the threat of nuclear destruction between the superpowers, and I see no contradiction in wanting to extend those efforts to reduce the threat of terrorist-mounted nuclear destruction. Rather, the proposal by the NRC indicates to me a willingness by the United States to stand by its pledge of nuclear non-proliferation by reducing the use, and likelihood of use, of nuclear weapons-grade fissionable material in non-defense research. I would frankly support any effort to further reduce the threat of nuclear weapon use and find in this proposal a most constructive plan to do just that.

I urge your consideration of my comments before concluding your action on the proposal now before you.

Sincerely,

George E. Brown Jr

George E. Brown, Jr.
Member of Congress

GEB:sds:vlr

DOCKET NUMBER
PROPOSED RULE PR-50 (67)
(49 FR 27769)

DOCKETED
USNRC

'84 OCT 12 A10:10

Radiation Center Oregon State University Corvallis, Oregon 97331 (503) 754-2341

October 8, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Branch

Gentlemen:

Re: Comments on the Commission's Proposed Rule Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

Oregon State University (OSU) would like to respectfully submit the following comments on the Nuclear Regulatory Commission's proposed rulemaking entitled, "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors," which was published in the Federal Register on July 6, 1984, in Volume 49, Number 131, pages 27769 through 27772.

In submitting these comments, we will attempt to address items specifically identified by the Commission in the Federal Register notice as being of particular interest to them. Likewise, we will attempt to minimize repeating comments we submitted as part of several earlier studies which were completed prior to the publication of this proposed rule. Presumably, information submitted previously is already part of the record being compiled for this proposal. However, in spite of this we do feel very strongly that a number of extremely valid issues were raised during the prerulemaking investigations and would like to make the observation that a number of these early comments seem to have been overlooked in drafting the content of the proposed rule as published, or they were dismissed by the Commission as solvable under the assumption that Federal Government funding would be made available. As a result of this, we feel compelled to reiterate several of our major concerns and will do so under the numbered topical headings which appear later in this submission. We sincerely hope that by repeating these noteworthy issues the Commission will be better able to understand why we do not feel at ease with the rationale underlying this rule or the potential impacts of the rule on the research reactor community, and why we earnestly hope the Commission will reexamine their position on this very important matter and ultimately conclude that the currently proposed rule is not the correct solution.

Before dealing with the more specific aspects of the proposed rule, Oregon State University would like to go clearly on the record as opposing the Commission's proposal on limiting the use of high enriched uranium (HEU) fuel on at least five different counts. First, we do not concede

Acknowledged by card. 10/15/84 pl

that for the FLIP-fueled TRIGA reactors that FLIP fuel should be considered weapons-grade high enriched uranium; second, we are convinced that this rule will have a serious negative impact on nuclear engineering educational programs and will definitely reduce the number of graduates with BS, MS, and PhD degrees in nuclear engineering as well as in other related areas such as radiation health. Furthermore, we believe it will cause unacceptable reductions in needed nuclear engineering research as well as in research in other vital engineering and scientific disciplines. Third, we feel there is a very low probability that the rule will accomplish the stated objectives now being used to justify its proposed adoption; fourth, we take strong exception to the required across-the-board replacement of perfectly good lifetime cores of HEU fuel, and finally, we believe that upon closer examination the Commission will reach the logical conclusion, as we did, that this rulemaking does not warrant the priority now being given to it by the Commission, that this rulemaking, regardless of the reasons being used to justify its proposal, is very premature in light of the hard facts which licensees can now count on in assessing the impact of the rule, and that there is an unprecedented emphasis to rather quickly reach a conclusion on limiting HEU use when this issue, like most other regulatory matters, would be better served by a more deliberate approach.

1. TRIGA FLIP FUEL IS NOT WEAPONS-GRADE HIGH ENRICHED URANIUM

Although the Commission has apparently decided that all non-power reactor fuel with U-235 enrichment greater than 20% is to be considered high enriched uranium suitable for weapons fabrication, and has used this rather arbitrary conclusion as part of the basis for extending the impact of the currently proposed rule to all non-power reactors with such fuel, we feel the obligation to continue to take exception to such a broad, and in our opinion, scientifically incorrect assumption. We further feel that such an unsound technical approach casts a shadow of doubt on the validity of the logic used to formulate this entire proposal.

Earlier communications to me and to the president of Oregon State University from former NRC Commissioner Victor Gilinsky in October of 1983, described to us his surprising and most alarming perception of the "explosive nature" of the 70% enriched FLIP fuel in our TRIGA reactor. However, we noted that Commissioner Gilinsky's statement did not document the scientific basis for his conclusion. While seemingly not a majority NRC opinion at the time, this concept has now apparently been endorsed by most of the remaining commissioners, as evidenced by the Commission's willingness to propose the rule we are now commenting on. With respect to Mr. Gilinsky's October 1983 statements on FLIP fuel, we would like to re-emphasize that FLIP-fueled TRIGAs use fuel which is only about 70% enriched and which has the ^{235}U contained in a fuel matrix consisting of uranium-zirconium-hydride with an erbium burnable poison. While perhaps it is not theoretically impossible to reprocess this type of fuel for uranium recovery, this fuel material is very much more difficult to deal with chemically than other types of reactor fuel more commonly used by non-power reactors, and at only 70% enrichment is most certainly the least desirable of all (so called HEU) fuels for theft and diversion. In addition, because of the lower peak power levels of the FLIP-fueled TRIGAs (conventionally 1 MWt), the fuel lifetime is much longer and each TRIGA facility has essentially its entire inventory of FLIP fuel in the core, irradiated to self-protecting radiation levels (greater than 100 rem per hour at 3 feet in air). Refueling of these reactors is an unusual rather than a usual event, which is why little or no fresh fuel is normally kept on inventory. Therefore, after considering this fact and the makeup of the unique fuel matrix, it is our contention that it is entirely sound to conclude that these facilities will at most be very low priority targets for SNM theft and diversion. As a result of this, we see no logical or technical reason why TRIGA FLIP fuel should be dealt with as weapons grade HEU, and specifically request that the Commission act on the widely recognized unique features of this fuel by incorporating an exemption for FLIP fuel into the rule should it reach the final phase of enactment.

2. THE PROPOSED RULE IS DAMAGING TO EDUCATION AND RESEARCH

In June of 1984, NRC Chairman Dr. Nunzio Palladino spoke before the American Society for Engineering Education at their meeting in Salt Lake City, Utah. During his presentation he clearly stated that revitalization of university programs in nuclear engineering was an essential ingredient in the recovery and continued welfare of the nuclear industry in this country. While we find such a statement to be refreshing, and most certainly agree, we also find the currently proposed Commission action to have an easily predictable impact which will be directly contrary to the goals spelled out in Dr. Palladino's statement.

There is no denying that the university research reactor is an essential instructional tool, particularly in the areas of nuclear engineering and radiation protection. In both of these areas we are presently facing a serious shortage of adequately trained personnel. Thus, in 1983 fifty-four universities in the U.S. offering nuclear programs (of which 27 are ABET accredited programs) produced only 431 BS NE graduates; 243 BS ME graduates with nuclear option; 325 MS graduates, of which about one-third are foreign nationals; and 124 doctorates, of which only 72 are U.S. citizens. These meager numbers are in sharp contrast to the heavy demand for adequately trained nuclear engineers and radiation protection specialists by utilities, industry, defense agencies, regulatory agencies, and universities. The manpower shortage problem is clearly demonstrated by the fact that in the current issue of Nuclear News one finds over 20 full-page-equivalents of advertisements, including one by the NRC, for personnel recruitment. Shutdown of university research and teaching reactors resulting from failure of universities to comply with the currently proposed HEU policy will undoubtedly weaken the quality of future graduates to a significant extent. It could also easily lead to a major reduction in the number of graduates in the broad areas of nuclear engineering, nuclear science, and radiation protection, thus ultimately inflicting serious detrimental effects upon the nation's nuclear safety program.

3. THE PROPOSED RULE WILL NOT ACHIEVE THE STATED OBJECTIVES AND SHOULD NOT REQUIRE DISPOSAL OF LIFETIME CORES

The ability of U.S. nuclear policies to influence similar actions by foreign governments is, at best, unpredictable. In a decision designed to reduce the possible theft or diversion of nuclear weapons material (which is one of the two major reasons for the currently proposed rule) the United States earlier decided against the commercial reprocessing of nuclear fuel from power reactors, but the rest of the world simply ignored our lead. In a similar manner, we have been told repeatedly by colleagues at research reactors located outside the United States that they are receiving no pressure to remove HEU fuel, that they have no intention of removing their HEU fuel before its lifetime has been reached, and that they will seek HEU replacement fuel as needed.

The international picture seems quite clear to us. The U.S. may be able to "encourage" the use of low enriched uranium (LEU) fuel in foreign (and domestic) reactors by limiting its supply when replacement fuel is needed, but it is obvious that the foreign reactors will receive no mandate to throw away usable HEU cores. By the same token, and for obvious economic reasons, U.S. reactors should be given equal treatment, and we request that the Commission modify the proposed rule on HEU to eliminate this clearly over zealous aspect of the proposal.

We also recognize that because the currently proposed rule is not going to include the most important sources of HEU that it cannot hope to contribute much towards achieving the stated objectives. Such a conclusion must also be reached by the Commission when it is recognized that U.S. Department of Energy research reactors will be unaffected, that at least one or two of the largest university research reactors, both using HEU, will not be affected for a long period of time, if ever, and that research reactor fuel as a category represents only a small fraction of the total U.S. traffic in HEU. In view of this, we wonder why such a rule is being pursued when the economic and academic costs are potentially so high and the benefits so minimal.

4. THE RULEMAKING IS PREMATURE BASED ON AVAILABLE FACTUAL INFORMATION (i.e., THE AFFECTED LICENSEES MUST HAVE POSITIVE COMMITTMENTS AND CONCLUSIVE TECHNICAL FACTS ON THE FOLLOWING POINTS BEFORE THE RULEMAKING IS ALLOWED TO PROCEED)

Whether or not the Commission continues with this rulemaking as originally proposed, or modifies the proposal based on comments received, there are a number of very crucial technical and administrative considerations which will remain a part of the proposed rule. These considerations, as spelled out in more detail below, will force operators of the affected nonpower reactor facilities to reach important decisions in order to deal with these new issues. Because of the added complexities and potential negative impacts associated with the solutions to many of the problems introduced by the proposed rule, it is very evident to us that a decision could easily be rendered by a number of universities to totally decommission their reactors.

The Commission itself acknowledges that successful implementation of the proposed rule depends on, at least, the success of the DOE RERTR program, the development of acceptable and available replacement fuel, and financial and operational support through DOE. But these issues are not yet settled! Why then, we respectfully ask, is the Commission so anxiously putting the regulatory cart before the horse? Shouldn't the affected licensee community be given the traditional opportunity to use known facts to formulate their comments on a rule which could easily determine their continued livelihood, rather than being forced to extrapolate from uncertainty and speculation as we are now doing.

To help emphasize our concerns in this area, we would like to briefly expand on the following points where we feel decisions simply must be reached and publicized before this rulemaking proceeds further.

a. Fuel Acceptability and Availability

Even under the assumption that the NRC has concrete evidence that TRIGA FLIP fuel can be readily used for weapons fabrication, we still have two major concerns regarding the acceptability (to us and to the NRC) of the new LEU TRIGA fuel manufactured by G.A. Technologies. First of all, the new fuel has been tested by the DOE only in long steady state runs to ascertain performance, burnup, etc. They have performed no testing from the pulsing standpoint, and none is planned. G.A. engineers have pulsed the fuel to some extent, but not under conditions of high burnup, and we have no idea if the NRC will accept their pulsing results. Furthermore, we do not know what the NRC will require in terms of license limitations on pulsing, which is a very important consideration to Oregon State University reactor operations and to several other research reactors. Additionally, the numerical values used to describe expected fission product releases in the event of fuel cladding failure (the fission product release fractions) have been carefully reviewed and accepted by the NRC for our current fuel. Since these values weigh heavily on the results of any projected accident scenario involving fuel cladding failure, they are of great importance in preparation of the facility Safety Analysis Report and Emergency Response Plan. At this time we are concerned about what these new values might be, if they have been deemed acceptable by the Commission, and how they will effect our existing accident projections and emergency response requirements. As a result of these factors, we feel that although G.A. Technologies may be in a position to manufacture LEU fuel for TRIGAs in adequate supply, there are a number of unknowns associated exclusively with the installation, use and licensing of such fuel for which we, the potential users, must have answers before we can accurately assess the impact of converting to such fuel. It simply makes no sense for us to be placed in the difficult position of being asked to deal with all of these unknowns in assessing the impact of this rule when the stakes are so high. Therefore, we respectfully request that this rulemaking be immediately put onto a hold status, or discontinued, until answers to these questions can be made available.

b. Financial Support

Everyone appears to acknowledge that funding is an essential ingredient for successful implementation of this rule. However, the proposed rule simply does not establish the needed vital link between federal funding and implementation. The implementation schedule required of licensees will only consider availability of financial support and there are no assurances that the implementation will be delayed if federal funding does not materialize. It is of paramount importance to clearly understand that as far as the Oregon State University reactor is concerned, and undoubtedly many other university reactors, without concurrent and concrete federal funding for all aspects of any projected refueling it will be impossible for us to consider implementing this rule and we will most certainly be forced to decommission our reactor.

We also believe that the funding scope being considered so far is too narrow in several aspects. Fuel costs will most certainly dominate the expenditures, but other costs such as transportation under NRC physical security rules, cask rental and cask user licensing, facility modifications to improve crane capacity, etc., support for additional manpower to prepare licensing documents, and assistance in meeting the modified Category I safeguards requirements for cooled (non-self-protecting fuel) will also be major items. For Oregon State University, and a number of other universities, the latter item alone could be very expensive, and could greatly interfere with our reactor operations depending on the cooling time involved.

In spite of the identifiable expenses, however, we cannot begin to assess the impact of this rule until we know the exact extent of the funding we can count on. If there is no funding, or it is inadequate, the consequence is simple, we decommission the reactor. Therefore, we repeat our plea to the Commission as stated above, a plea we feel is both logical and fair, to halt this rulemaking process until all of us have the information we need to proceed!

c. Licensing

The tremendous potential impacts related to licensing are now obvious to everyone involved in this rulemaking. The proposed rule gives no form of relief from standard licensing practices and we are, therefore, forced to assume that relicensing could, should a hearing be involved, be a long, expensive, and perhaps terminal endeavor for at least some members of the university reactor community. We believe the Commission recognizes the problems in this area, but the rule offers nothing new. Basically, it is the reoccurring uncertainty which we must object to once again.

d. Operational Items

Implementation of significantly increased and prohibitively strict physical security measures to protect what will become non-self-protecting fuel, handling highly irradiated and insufficiently cooled fuel, which was purposely made more radioactive to reduce the threat of diversion and theft, and a major interruption to operations and to our academic programs are all items we feel have been grossly underestimated by the Commission in developing this rule. The uncertainties associated with these items alone are sufficient for us to strongly oppose the proposed rule at this time.

In conclusion we would first like to state that Oregon State University appreciates the opportunity to submit these comments. As you can see, we are very concerned about this proposed rule with its serious consequences, and by the assumptions being used to include FLIP-fueled TRIGAs in the refueling effort. We sincerely hope the Commission will carefully evaluate the issues raised in our comments, and believe that by so doing it will become very clear why we feel it is a mistake to continue this rulemaking effort. We will be most happy to provide additional information at your request.

Yours sincerely,

C. H. Wang
Reactor Administrator
Director, Radiation Center

CHW:jrl
cc: USNRC, Deputy Executive Director for Operations, Washington, D.C. 20555 (Attn. Mr. Victor Stello)
USNRC, Standardization & Special Projects Branch, Division of Licensing, Washington, D.C. 20555 (Attn. Mr. Robert Carter)
USNRC, Documents Management Desk, Washington, D.C. 20555
USNRC, Region V, Walnut Creek, California, (Attn. Regional Administrator)
Director, Oregon Dept. of Energy, Salem, OR
Mr. Harold Young, USDOE, Washington, D.C.
Mr. Wade Richards, Chairman, ANS-15 Standards Committee
Mr. Don Feltz, Texas A&M University
Dr. Bill Wilson, Washington State University
Dr. T. D. Parsons, Vice President for Administration
Prof. S. Binney
Prof. B. Dodd
Prof. A. Johnson
Mr. T. Anderson

DOCKET NUMBER
PROPOSED RULE PR-50 (68)
(49 FR 27769)

DOCKETED
USNRC

'84 OCT 12 P2:31

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Attn. Docketing + Service Branch
Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555

Oct. 8, 1984

Dear Sir.

This letter is re the HEU Conversion Rule (49 Federal Register 27769)

I support the conversion of all nuclear reactors which use highly enriched uranium. The cost of such conversion seems irrelevant compared to the danger of theft of the weapon grade fuel.

I urge you to promptly implement this action: This can be a signal to the rest of the world that the U.S. takes seriously the problem of the proliferation of nuclear weapons.

Thank-you for your prompt consideration.

Yours sincerely,

Lu H. Barber
LUIS H. BARBER
728 OCEAN BLVD
SHELL BEACH CA 93449

Acknowledged by card. 10/15/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50 (66)
(49FR 27769)

To The Secretary of The Nuclear Regulatory Commission.
Dear Sirs,

I am writing in support of The proposal before The Nuclear Regulatory Commission To require nuclear research reactors To convert from highly enriched uranium To low enriched uranium. As a registered voter and Taxpayer I strongly urge you To carry out these conversions as soon as possible.

Thank You.
John M. Bass
John M. Bass

John M. Bass
3 Hermosa Pl.
Menlo Park, CA. 94025

DOCKETED
USNRC
'84 OCT -9 A11:54
OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Acknowledged by card 10/9/84
pd

DOCKET NUMBER
PROPOSED RULE PR-50 (74)
(49 FR 27769)

October 10, 1984

Dear People at NRC –

Because ~~of~~ the alternate use of highly enriched uranium fuel (in atomic weapons) ~~is~~ places my children – and all life on the planet at risk – I sincerely urge you to convert those 31 nuclear reactors around our country to Low enriched fuel. ASAP!

Your children will thank you
I thank you.

Sincerely,

Melinda Maxwell-Smith
4048 Benedict Cnyn. Dr.
Sherman Oaks, Ca 91423

DOCKETED
USNRC
'84 OCT 17 A10:17
BRANCH

~~Acknowledged by card. 10/22/84 pd~~

90

LOS ANGELES, CA
PM
10 OCT
1984

DOCKET NUMBER
PROPOSED RULE PR-50 (73)
(49 FR 27769)

DOCKETED
USNRC

'84 OCT 15 P1:15

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

The Secretary of the
Nuc. Reg. Commission
Washington
DC 20555

© USPS 1984

I support your 10 10 84
proposal to convert 31 nuclear reactors around the nation to low-enriched fuel, which then cannot be used in a weapon. Thank you and PEACE!

David Seidman
David Seidman 4163 Monroe Street
LA CA 90029
(213) 664 5373

Acknowledged by card. 10/16/84
pd

DOCKET NUMBER
PROPOSED RULE PR-50 (70)
(49 FR 27769)

DOCKETED
USNRC

October 10, 1984

'84 OCT 15 P1:03

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D. C. 20555

I am writing to let you know that I strongly support the proposal before the Commission to require nuclear research reactors to convert from highly enriched uranium to low enriched uranium fuel.

I believe that these conversions should be implemented immediately, not at some date in the future. I also believe that they are vital to our safety and to our national security.

Thank you.

Sincerely,

Roberta Riley

Roberta Riley
8033 Rayford Drive
Los Angeles, California 90045

Acknowledged by card 10/16/84
pd

2418 Rayburn House Office Building
Washington, D.C. 20515
(202) 225-3976

District Office:
8425 West 3d Street
Suite 400
Los Angeles, California 90048
(213) 651-1040

Congress of the United States
House of Representatives
Washington, D.C. 20515
HENRY A. WAXMAN
24th District, California

Committees:
Energy and Commerce
Chairman, Subcommittee on Health and the Environment
Government Operations

Burt Hoffman
Administrative Assistant

DOCKETED
USNRC

'84 OCT 19 A10:54

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

October 11, 1984

DOCKET NUMBER
PROPOSED RULE PR-50 (19)
(49 FR 27769)

Samuel J. Chilk
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Docketing & Service Branch
Washington, D.C. 20555

Dear Mr. Chilk:

The U.S. Nuclear Regulatory Commission, in August 1982, proposed to exercise its licensing authority to reduce "to the maximum extent possible" the use of highly enriched uranium (HEU) in reactors under its direct control. In the interests of national and international security I urge the commission to promptly implement this proposal.

The NRC could greatly minimize the risk of theft or diversion of the weapons-grade material HEU by requiring reactors to convert to low-enriched uranium (LEU). This conversion would not only reduce the risk of the weapons-grade fuel being stolen by terrorist groups or nations intent on acquiring nuclear weapons, but would also serve as proof to other nations that the United States is committed to nonproliferation of nuclear weapons.

HEU is an essential ingredient in making nuclear weapons, but this bomb-grade uranium is not an essential ingredient to the operation of the 46 reactors in this country which use it.

I commend the NRC for proposing the necessary action needed to reduce the grave and serious threat of the availability of HEU. Please accept this letter as a record of my support of the proposal before the deadline for public comment expires on November 2, 1984.

With kind regards, I am

Sincerely,

Henry A. Waxman

HENRY A. WAXMAN
Member of Congress

10/18..To OCA for Appropriate
Action..Cpys to: RF, EDO
84-0999

HAW:kl

Acknowledged by card 10/22/84 pa

cc: Nunzio J. Palladino
Steven Aftergood

10/11/84

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(72)

DOCKETED
USNRC

'84 OCT 15 P1:04

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Attn: Docketing & Service Branch
Sec. of Commission
US Nuclear Regulatory Commission
Washington DC 20555

RE: HEU Conversion Rule
(49 Fed Register 27769)

Dear Sirs:

I am writing to express my concern about all nuclear reactors which use enriched uranium. I believe that the conversion of HEU fuel to LEU fuel is extremely urgent + important to the safety of us all. I am for the ~~st~~ scaling down of anything that could be used for a nuclear weapon. I don't believe it is necessary to have these materials available - material which could be used for an atomic bomb.

This conversion would be worth a great price to me + ultimately to the rest of the world, I believe.

Hope you will consider this an urgent and serious issue + implement this proposal which is before the Commission as soon as possible.

A concerned citizen + human being.

Thanks.
Marcia D. Crews
11621 Ohio #5
LA, Ca 90025

Acknowledged by card. 10/16/84

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(71)

USNRC

'84 OCT 15 P1:03

OFFICE
DOCKET

from the desk of

Dotty and Jack

3355 Bennett Drive
Los Angeles, CA 90068
October 11, 1984

Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

It would mean a great deal to know that you will support the proposal to convert 31 nuclear weapons around the country to low-enriched fuel, which cannot be used in a weapon.

This makes a lot of sense in our world today.

Your cooperation relative to this will be very much appreciated.

Sincerely,

Dorothy Garber

Mr. & Mrs. Jack Garber

Acknowledged by card. 10/16/84

RISØ

Risø National Laboratory

Postbox 49
DK-4000 Roskilde, Denmark
Phone (02) 37 12 12, Telex 43 116
Cable address: Risatom

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769) (83)

DOCKETED

'84 OCT 23 A11:05

Date 1984-10-12
Your ref.
Our ref. 50101-06
Dept. Management

REGISTERED AIR MAIL

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington DC-20555

Attention: Docketing and Service Branch

Dear Sirs,

Proposed Rule for the USNRC for the Conversion of Research Reactors to Low Enriched Fuel

We have studied the proposed rule on above mentioned subject which was published in the Federal Register, Vol 49, No. 131 (July 6, 1984).

As the proposal might have implications to non-US research reactors, we have found it appropriate to submit our general comments as enclosed in ANNEX to this letter. ./.

Yours sincerely

Ingvard Rasmussen
Deputy Director

Acknowledged by card 10/23/84.

RISØ

1984-10-12/IR/LH
J.nr. 50101-6

ANNEX

SUMMARY OF VIEWS

'84 [illegible] 23 A11:06

on Potential Termination of the Supply of Highly Enriched Uranium for the Danish Research Reactor DR 3

1. Since 1980 Risø National Laboratory has participated in the international research on lower enriched fuel for research reactors, which was initiated in the context of US nuclear non-proliferation measures.

   These efforts have been governed by the objective of the USDOE research program on Reduced Enrichment for Research and Test Reactors (RERTR), which is "to develop research and test reactor fuels which will allow substitution of uranium of low enrichment (LEU, less than 20%) for high enrichment (HEU), and which will not significantly affect reactor performance characteristics or fuel cycle costs".

2. Risø has with deep concern noted the recently issued Proposed Rule (Fed. Reg. Vol. 49, No. 131, July 6, 1984) of the USNRC on "Limiting the use of HEU in Domestic Research and Test Reactors", which in our situation might imply a premature termination of the HEU supply.

3. Reactor DR 3 is the only high-flux neutron source in Denmark and utilization has been high since the commissioning in 1960. Comprehensive research programmes of international standard in the fields of solid state physics and materials technology are based upon this facility, which also provides the Danish market with short-lived isotopes for medical purposes and with neutron activation analysis services. Also commercial irradiation services for industry have grown to a significant scale.

Furthermore, the operation and monitoring of DR 3 and the associated handling of high-level radioactive material is one of the major sources to practical experience, which enables Risø to perform its duties in advising Danish authorities on nuclear matters. Such experience is needed in a country without nuclear power, but still maintaining the nuclear option in the national energy planning.

4. It follows from the preceding statement that it is considered a high national priority to maintain DR 3 at a state of advanced technology and high availability, and to ensure that any change in technical specifications would not deteriorate significantly the reactor performance or the fuel cycle economy.

5. Our present position as regards potential conversion can be summarized as follows:

   (a) Guaranteed HEU-supply will enable present mode of DR 3 operation to be maintained till early 1988.

   (b) Potential conversion to 45%-enriched fuel type would imply marginal losses in reactor performance and moderate increase in fuel cycle costs, which might be accomodated. Licensing should be relatively uncomplicated.

   (c) It remains to be demonstrated that 20%-enriched fuel can meet the objectives of the RERTR-program and be made available on a commercial and competitive basis. Furthermore, licensability of low-enriched fuel for the Danish research reactor depend heavily upon access to a well-established licensing basis, generated by a major country.

   (d) Facilities for final nuclear waste disposal have not yet been established in Denmark and may not materialize in a forseeable future, taking into account the prevailing attitude regarding nuclear power. It is therefore vital for the continued operation of DR 3 that the USA will continue to receive spent fuel from Risø, either for reprocessing or disposal.

   (e) Until the objectives of the RERTR-programme has been clearly met, a request for conversion to low enrichment might be economically prohibitive to a research center with modest ressources, and would have fatal influence upon its scientific progress and competitive capability.

DOCKET NUMBER PR-50 (91)
PROPOSED RULE (49FR 27769)

[illegible]

October 12, 1984

'84 OCT 26 A10:18

[illegible]

Statement of RONALD BAKAL, Esq.

Before

The Subcommittee on Energy Research and Production

and

The Subcommittee on Energy Development and Applications

of the

House Committee on Science and Technology

My name is Ronald Bakal. I am an attorney and a member of the Nuclear Law Center, a group of public interest attorneys who assist public groups in nuclear cases. We have been deeply involved in matters in which a public group challenged the adequacy of security at a local research reactor because it possessed weapons-grade nuclear materials with grossly inadequate security.

I understand the NRC has proposed a new regulation which would require research reactors to convert from weapons-grade fuels to low enriched, non-weapons-grade material. The rule has two purposes: to provide protection against the unique risks associated with potential theft of material from which a nuclear bomb could be manufactured, and to remove a major obstacle to completing a long-standing foreign policy objective of converting foreign research reactors from highly enriched uranium (HEU) and reducing the amount of such weapons materials that are internationally available for theft or diversion to weapons purposes.

Acknowledged by card. 10/29/84 pd

Despite the fact that conversion seems to be a relatively quick and simple matter-- DOE simply retrieving the HEU fuel it has loaned these reactors and substituting LEU replacement fuel-- and despite the fact that it appears Congress is to pick up the tab involved, and has already appropriated a substantial portion of it, there remains some residual opposition among the potentially affected licensees. Some of the arguments appear particularly irrational, as the one that requiring conversion to LEU will cause public outcry and legal interventions against the research reactors. Exactly the opposite is the case.

UCLA, a reactor with HEU fuel, closed down permanently and withdrew its renewal application a week before it was to go to hearing on the serious inadequacies in its security. Intervenors wanted it to convert to LEU; it resisted. As in all cases to date, Intervenors have opposed the presence of HEU and urged replacement with LEU; it has never been the other way around.

Reactors with HEU fuel cannot meet their burdens in demonstrating sufficient security to protect against theft of weapons-grade materials. If reactor operators have legal concerns, conversion is the best answer for them, because the security needs go down, as well as public concern.

Of the hundreds of license amendments for research reactors, there has never been an Intervenor, even in matters far more controversial than conversion and where the change was clearly in the unsafe direction (e.g., an order of magnitude increase in power) as opposed to the clear reduction in risks involved with removing weapons-grade fuels from campuses. No interventions can be expected to occur in license amendment cases for HEU conversion, but they can be virtually guaranteed if these reactors do not convert and keep bomb-grade materials on site. This is the single most aggravating issue to public groups concerned with research reactors in their neighborhoods, and failure to convert can be expected to result, particularly in light of the UCLA case, in a flurry of legal actions and other public opposition to continued presence of weapons-grade material in their communities.

UCLA withdrew its application for renewal of its full license in large measure because it had weapons-grade uranium on site and inadequate security. Research reactor operators who wish to avoid the same public outcry should not stand in the way of conversion to LEU; if the conversion rule is overturned, it will likely result in precisely the kind of opposition to their facilities they say they so desire to avoid.

Conversion from weapons-grade fuels is really in the best interests of all parties. Public groups want bomb materials out of their neighborhoods. Reactor operators want reduced security problems and reduced risk of public opposition. And we all want, don't we, reduced risks that a terrorist group or state might acquire a clandestine nuclear weapon. Clear-sighted perception of the issue would indicate that it is in everyone's interests to remove weapons-usable materials from underprotected locations here and abroad.

#

Ronald Bakal 10/23/84.

Ronald Bakal, Esq.
8447 Wilshire Blvd.
Suite 300
Beverly Hills, CA 90211
(213) 655-0242

DOCKET NUMBER PR-50 (75)
PROPOSED RULE
(49 FR 27769)

Oct 13/84.

Nuclear Regulatory Commission:

I support your proposal to convert 31 nuclear reactors around the country to low-enriched fuel, which cannot be used in a weapon.

Sincerely
Gina L. Bearson
25911 Corriente Lane
Mission Viejo, Ca.
92691

DOCKETED
OCT 17 1984
DOCKETING & SERVICE BRANCH
SECY-NRC

SANTA ANA, CA 927
PM 1
OCT 1984

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Docking and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington D.C. 20555

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Acknowledged by card 10/22/84 pa

DOCKET NUMBER
PROPOSED RULE PR-50 (78)
(49 FR 27769)

October 14, 1984

'84 OCT 19 P1:36

Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Commissioners:

This is just a short note to inform you that we strongly support your proposal to convert the 31 nuclear reactors around the U. S. to low-enriched fuel. The potential risk for nuclear weapons proliferation in this age of rising world wide terrorism should be checked and limited whenever possible. Thank you for your consideration of this vital matter.

Yours very truly,

Lawrence Miles for

Mr. & Mrs. Lawrence Miles
1046 Brighton Ave.
El Centro, CA. 92243

Acknowledged by card 10/22/84
pd

99

DOCKET NUMBER
PROPOSED RULE PR-50 (76)
(49 FR 27769)

GREENPEACE U.S.A.

2007 "R" St. N.W.
Washington, D.C. 20009

Tel. (202) 462-1177
Tlx. 89-2359

DOCKETED
USNRC

'84 OCT 18 A11:41

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

15 October 1984

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir or Madam.

Greenpeace has a long term commitment to control the proliferation of nuclear material in order to halt the spread of nuclear weapons. Our one million supporters world-wide, 450,000 of which are in the United States, are dedicated to global environmental security. On behalf of these supporters, I am writing to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried our.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the US takes seriusly the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel world-wide.

But in order to be effective, it must be non-voluntary and it must be promptly implemented.

Thank you for your consideration,

Very truly yours,

Sebia Hawkins

Sebia Hawkins

Acknowledged by card. 10/22/84
pa

REGIONAL OFFICES: BOSTON, CHICAGO, DENVER,
HONOLULU, JACKSONVILLE BEACH, SAN FRANCISCO, SEATTLE

100

DOCKET NUMBER
PROPOSED RULE PR-50 (84)
(49 FR 27769)

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY · DAVIS · IRVINE · LOS ANGELES · RIVERSIDE · SAN DIEGO · SAN FRANCISCO   SANTA BARBARA · SANTA CRUZ

COLLEGE OF ENGINEERING
DEPARTMENT OF NUCLEAR ENGINEERING

BERKELEY, CALIFORNIA 94720

October 16, 1984

'84 OCT 23 A11:07

License No. R-101

Docket No. 50-224

Secretary of the Commission
Attention: Docketing and Service Branch
United States Nuclear Regulatory
Commission
Washington, District of Columbia 20555

Subject: Proposed rule on limiting the use of high enriched uranium in domestic research and test reactors (49 FR 27769)

Gentlemen:

The proposed rule 10 CFR 50.64 defines High Enriched Uranium (HEU) as fuel in which the weight percent of U-235 in the uranium is 20% or greater. Low Enriched Uranium (LEU) is fuel in which the weight percent of U-235 in the uranium is less than 20%.

Standard TRIGA reactors use fuel in which the weight percent of U-235 is 20% or less.

As a consequence of the above definition, standard TRIGA reactors using 20% enriched uranium would be categorized as HEU reactors when fresh fuel arrives from the manufacturer until the fuel is used in the reactor. The proposed rule does not address this specific problem nor exempt this 'transition' period from the HEU definition.

We believe that the proposed rule should define HEU as fuel in which the weight percent of U-235 in the uranium is greater than 20% and LEU as fuel in which the weight percent of U-235 in the uranium is 20% or less.

Sincerely,

Thomas H. Pigford
Reactor Administrator

THP:sf

cc: Commissioner James Asselstine

Acknowledged by card. 10/23/84 pd

MEL LEVINE
27TH DISTRICT, CALIFORNIA

COMMITTEES:
COMMITTEE ON FOREIGN AFFAIRS
COMMITTEE ON GOVERNMENT
OPERATIONS

Congress of the United States
House of Representatives
Washington, D.C. 20515

WASHINGTON OFFICE:
[illegible] CANNON HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515
TELEPHONE: 202-225-6451

DISTRICT OFFICE:
5250 WEST CENTURY BOULEVARD
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LOS ANGELES, CALIFORNIA 90045
TELEPHONE: 213-643-0836

101

DOCKETED
USNRC

'84 OCT 22 A11:06

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

October 17, 1984

Mr. Samuel J. Chilk
Secretariat
Office of the Secretariat
Docketing and Service Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Chilk

I am writing regarding the Nuclear Regulatory Commission's proposal to require owners of non-power reactors to use low-enriched uranium fuel in place of the highly-enriched uranium currently used. I strongly support this proposed NRC rule.

Eliminating the use of bomb-grade quality uranium in research reactors will reduce the possibility of theft by terrorists, and its subsequent diversion to weapons use. It will demonstrate a commitment by the United States to the non-proliferation of nuclear weapons and will reduce the amount of highly-enriched uranium available internationally.

It is my understanding that domestic research will not suffer with the use of low-enriched uranium. That being the case and since in some instances individual schools have in their possession enough kilograms of highly-enriched uranium to build an atomic bomb, the conversion should be implemented as soon as it is economically feasible to do so.

I appreciate having this opportunity to express my views in support of the NRC proposed rule.

Sincerely,

Mel Levine

Mel Levine
Member of Congress

ML/ams
cc: Chairman Nunzio Palladino

10/23...To EDO for Appropriate Action...Cpys to: RF, Docket..84-1013

102

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(82)

NUCLEAR REACTOR LABORATORY
AN INTERDEPARTMENTAL CENTER OF
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

O.K. HARLING
Director

138 Albany Street Cambridge, Mass. 02139
(617) 253-4202

L. CLARK, JR.
Director of Reactor Operations

DOCKETED

'84 OCT 22 P1:23

October 19, 1984

Secretary of the Commission
Attention: Docketing and Service Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49 FR 27769)

Gentlemen:

In response to the Federal Register notice of July 6, 1984 (49 FR 27769-27772), the Nuclear Reactor Laboratory at the Massachusetts Institute of Technology is pleased to submit its comments on the above proposed rule.

We are most certainly in accord with the goals that underlie the proposed rule (10 CFR 50.64), namely minimizing the risk of diversion of highly enriched uranium (HEU), a potential nuclear weapons material. MIT would be willing to convert its research reactor to low enriched uranium fuel (LEU), when and if acceptable fuel of this type becomes available, if it can be utilized without significant penalty in reactor performance, and if funding is provided to defray all conversion costs.

As we interpret the proposed rule, the MIT Reactor (MITR-II) would qualify as having a "core of special design that could not perform its intended function without using HEU fuel" (proposed paragraph 50.64(b)(3)iv)) and, hence, would not be required to convert to LEU or to medium enriched uranium (MEU) until such time as either of these becomes available. It is, therefore, imperative that any final rule incorporate at least this temporary exemption. We have not had the time or resources to conduct the reactor physics computer studies needed to determine with any precision the effect of future LEU on neutron flux levels and spectra in the MITR-II experimental facilities and thus whether the reactor would continue to qualify as having a "unique purpose" if fueled with future LEU (e.g. 8-9 g U/cc).

The conversion potential for the MITR-II and other aspects of the proposed rule are further discussed below.

Conversion Potential for the MIT Research Reactor

The feasibility of converting research reactors from HEU fuel to LEU fuel was discussed in the LEU study report, Reference 1, and it was pointed out that the reactors at MIT and the University of Missouri, Columbia, could not be converted with either currently available fuels or the advanced fuels under development in the Reduced Enrichment for

Acknowledged by card. 10/23/84 pd

Research and Test Reactors (RERTR) Program of Argonne National Laboratory. For the MITR, in oversimplified terms, the core support structure and core tank limit the number of fuel positions to a maximum of 27, and this figure cannot be expanded without rebuilding the reactor. Since it is desirable to use at least three of them for experiments and irradiations, 24 positions are normally filled by fuel elements. It requires 18 elements for the reactor to go critical, even with the control blades fully retracted, and the extra reactivity provided by the six additional elements is needed to maintain criticality when experiments are inserted in the reactor and when the reactor operates under its normal operating conditions, i.e. at 5 MW with attendant xenon poisoning and slightly elevated temperatures, and when all elements have some of the uranium-235 burned out to one degree or another. In terms of U-235 in the core, reducing the enrichment from 93% (HEU) to 20% (LEU) is the equivalent of trying to operate the reactor with only five and a fraction HEU elements in the core. Obviously, any significant reduction in enrichment will shut down the reactor, and any reduction at all will reduce the burnup possible and hence increase fuel fabrication and transportation costs by limiting the length of time that fuel can be used in the core.

It is possible in some reactors today to compensate for reduced enrichment by adding more uranium (and thus maintaining the U-235 fissionable isotope at the level required for roughly comparable performance) by:

1) enlarging the core, but this cannot be done in the MITR-II for the reasons given above;

2) increasing the U concentration in the elements, but the MITR-II is already at the state-of-the-art maximum, 1.6g U/cc, the same as used in DOE's Advanced Test Reactor (ATR);

3) thickening the fuel plates that contain the uranium (at the expense of the cooling water channel thickness); a recent MIT master's thesis[2] indicates that some slight gain may be achieved in this area.

The RERTR goal over the next five years is to develop and demonstrate LEU fuels with concentrations up to 7.0g U/cc by 1989[3]. MIT (and Missouri) needs an LEU (20% U-235) concentration of about 8.6g U/cc. Only expensive computer calculations and/or critical experiments can determine the value with any precision, although it appears that at the 7.0g U/cc concentration an intermediate enrichment should be feasible. However, achieving the RERTR goal and meeting the schedule must both be viewed with uncertainty.

An alternative to the RERTR program for reducing proliferation risk is the DOE Extended Life Aluminide Fuel (ELAF) test project due to be completed in about one year[4]. DOE is irradiating mini-plates in the ATR with the goal of demonstrating more highly loaded HEU fuel that can be run in reactors to about double the present burnup limits. This would reduce the proliferation risk by roughly halving the number of elements that need to be fabricated, transported and reprocessed. In addition, negligible amounts of plutonium are generated and there would be substantial economic benefits.

Economics are an important consideration with regard to the conversion potential for the MITR and for other university research reactors. The Institute cannot afford to incur more than very nominal conversion expense. In this category would be costs for any reactor modifications that may be required, for reactor physics and thermal-hydraulics studies, for preparation of revisions to the MITR Safety Analysis Report, and for a public hearing if required. A license amendment will be required for conversion to LEU or MEU (medium enrichment uranium), and the experience at University of California, Los Angeles, raises the likelihood of similar protracted and costly litigation at other reactors. This situation could improve if the Commission adopts a recommendation of its Advisory Committee on Reactor Safeguards (ACRS) regarding the possibility of hearing rules for research reactors that are different from those for power reactors.[5]

Analysis of the Benefits of Converting to LEU

Initial reactions to any proposal to convert reactor fuel from HEU to LEU are understandably in favor of doing so. This is particularly true when responsible individuals recommend minimizing inventories of HEU.[6] Unfortunately the benefits of converting from HEU to LEU in a small way (which is all that the proposed rule would accomplish), or even in a large way, are far from clear cut.

It has been pointed out by others[1,7] that NRC-licensed research reactors utilize 10% or less of the HEU fuel consumed in the U.S., Department of Energy research and test reactors being responsible for 90% or more. Hence, even if all NRC-licensed research reactors are converted, only a negligible fraction of the HEU traffic will be eliminated, and the only reactors affected will be those with relatively small inventories (less than 5 kg unirradiated uranium each). Since nearly all of the HEU will still remain in circulation, it appears that the NRC policy will reduce the risk in only a minor way, even if the remaining HEU is maintained under tighter security.

A stated objective of the NRC policy is to encourage foreign reactors to convert, but we do not believe it likely that this small gesture by the U.S. will be effective in persuading them that they should follow such a U.S. example. Highly enriched uranium is after all the best fuel for high performance research reactors.

Even if all reactors were to be converted (which seems unlikely), there still appears to be a serious flaw in the argument that conversion to 20% enriched fuel will solve the problem. Contrary to the general opinion that a nuclear weapon cannot be made from 20% enriched uranium, an Atomic Energy Commission report on "Critical Dimensions..."[8] and the Congressional Research Service's "Nuclear Proliferation Factbook"[9] both show about 250 kg of uranium as the fast critical mass for reflected 20%-enriched uranium, or about one-half a cubic foot. "Nuclear Proliferation and Safeguards", by the Office of Technology Assessment[10], reports that the total weight of such an explosive would make it "impractical", without explaining for what purpose such a device would be impractical.

Two points should be made here. First, Zebroski[11] has assessed the resources in manpower, facilities and weapons-grade nuclear material required to develop and fabricate a reasonably reliable weapon from HEU and has indicated that, in any event, such a project is difficult and requires major investments in time, equipment and especially skilled manpower in many disciplines. It thus appears that the complete elimination of weapons-grade materials, both HEU and plutonium (not a practical goal), in favor of LEU would not change an easy weapons development task into a difficult one, but rather it would only make an already very difficult task more so. Second, given that 20% enriched uranium is reported to be physically capable of attaining fast criticality, a terrorist need not actually achieve the difficult goal of building a bomb but need only publicize a claim of success in order to blackmail his victims. It thus appears that conversion to LEU does not achieve the desired security. Another factor to consider is the extent to which plutonium is generated in LEU fuel in comparison with the negligible amount that results from use of HEU.

The Commission invited comments on the extent to which economics should influence Commission actions. Economics must be considered, just as it is in every other aspect of our lives where the degrees of health and safety are at issue. There is a residual risk, but making it a zero risk is unattainable and trying to do so is very costly. Zebroski has rated the various sources from which weapons or weapons materials might be illegally procured and has classified research reactors as being essentially at the bottom of the list of desirable targets.[11] The use of DOE's ELAF fuel mentioned above would reduce fuel fabrication and shipping costs.

Worth of the MITR Inventory as Weapons Materials

MIT's reactor fuel inventory is classified as having "moderate strategic significance" (corresponding to the International Atomic Energy Agency's Category II), which means basically that the unirradiated fuel inventory cannot exceed 5 kg.[12] Irradiated fuel that produces a dose rate in excess of 100 rem/hour at a meter (unshielded) is defined as "self-protecting" and is exempt from the 5 kg limit; MIT's irradiated fuel is orders of magnitude in excess of the 100 rem/hour level and retains its "self-protecting" feature for about three decades after removal from the reactor, thus rendering it practically inaccessible for diversion purposes.

While the unirradiated fuel can amount to as much as 5 kg, even this is a small fraction of what is required to construct a weapon. This means that multiple, successful theft attempts must be carried out in order to divert sufficient material, and it makes research reactor fuel a relatively unattractive target. Since 5 kg is the upper limit, inventories are usually less, often much less. MIT's practice, except just prior to refueling, is to maintain an inventory in the hundreds of grams rather than in the thousands. Therefore, the inventory is a much smaller fraction of the amount needed and is an even less attractive target. It should also be pointed out that HEU at university research and test reactors is protected under security plans approved by NRC.

Comments on Proposed Rule 10 CFR 50.64

MIT appreciates that the Commission, in developing the proposed rule, has attempted to construct it in such a manner as to ameliorate some of the problems that will face reactors required to convert to LEU.

If the Commission decides that it is necessary to adopt the proposed rule or something similar, MIT submits the following comments for NRC consideration.

Paragraph	Comment
50.64(b)(3)	The temporary exemption afforded the MIT Reactor by the definitions of "unique purpose" is essential until acceptable LEU becomes available (probably more than five years in the future) and a continued exemption may be necessary if the MITR is to maintain its performance at effective and efficient levels.

Paragraph	Comment
50.64(c)(2)(i)	"Acquire no additional HEU fuel" should be construed to mean that no additional HEU fuel shall be started in fabrication, i.e. all fuel in existence or in fabrication for a reactor should be utilized if this can be accomplished on a reasonable schedule. Economics should be considered, and there is no need for expedited rule making.[5]

Paragraph	Comment
50.64(c)(3)	The meaning of this paragraph is not at all clear. It might be possible for the MITR-II to achieve criticality with MEU at some enrichment such as 70% U-235. Would this be required, even though such fuel would provide no excess reactivity to permit operation at 5 MW, to allow the installation of experiments or to provide for operation when the fuel has been depleted by burnup?

MIT recommends that the requirement to use fuel with an enrichment as close to 20% as is available and acceptable be replaced with a requirement to use DOE's ELAF fuel with an HEU loading as high as is available and acceptable.

Paragraph	Comment
50.64(d)(2)	This paragraph requires the submission of a proposed schedule for conversion based on the availability of replacement fuel and consideration of factors such as the availability of shipping casks, financial support and reactor usage. In view of the uncertainties associated with at least the first three items listed, it is believed that adoption of the rule at this time is premature.

Paragraph	Comment
50.64(d)(3)	The MIT Reactor and probably a number of others will require license amendments when and if conversion to LEU or MEU takes place. Under present NRC practices we understand that issue of a license amendment provides an opportunity for interested parties to intervene and request a hearing. Since the purpose of the proposed rule is to reduce the risk to the health and safety of the public, only those who contend that the proposed rule increases the risk, i.e. who favor continued use of HEU, should be permitted to intervene. Potential intervenors have had ample opportunity to request hearings on other questions during earlier licensing actions and should not be afforded another unrestricted opportunity especially when the license amendment is related to a relatively narrow issue.

In the mid-1970's MIT went to great expense to renovate and update its research reactor so that it is now the "newest" and one of the best university research reactors in the U.S. This was accomplished with "state-of-the-art" HEU fuel of the type used by nearly all high performance reactors. The Institute now deplores the amount of time that it must expend on the HEU-LEU issue but also recognizes that it is a major issue that transcends MIT's interests and that it must be addressed. We hope that the Commission will eventually agree with Zebroski that "to find even residual public risk from diversion (of HEU from university research reactors)...it is necessary to assume nationally sponsored terrorism" exceeding "mere criminal or terrorist capabilities".[11]

We believe that the last section, "Added Measures for Consideration", of Zebroski's paper at the June 1984 ANS meeting, including expeditious communication with DOE response teams, is worthy of careful evaluation by the Nuclear Regulatory Commission in its consideration of the proposed rule on conversion to LEU.

In closing, we urge that the Commission resolve this problem in a manner that will minimize the loss of nuclear technology educational and research capabilities in the U.S.A. Many examples of the types of activities that would be curtailed were described at a 1983 symposium on research reactor utilization(13). If the MIT Research Reactor specifically were forced to close, the impact would be felt not only by the Nuclear Reactor Laboratory but also by seven other interdepartmental laboratories and academic departments at MIT and by 27 additional universities, hospitals and other nonprofit research institutions that used the MIT Reactor during the past year. A brief and incomplete listing of general research areas for that period includes:

neutron scattering research studies of the wave properties of thermal neutrons, the diffraction physics of neutrons and crystals, and the molecular dynamics of organic compounds;

development and testing of innovative candidate alloys for fusion reactor first wall materials, e.g. by tailored microstructure to enhance irradiation performance, and by studies of the effects of simultaneous fatigue, temperature cycling and irradiation;

development, and demonstration on the MIT Reactor, of methods for closed-loop, digital control of nuclear reactors during both steady state and transient operation;

neutron activation analysis studies of geologic samples to improve our understanding of geologic processes, e.g. the origin and evolution of volcanic rocks that erupt in various plate tectonic regimes of the earth and of sediments in oceanic systems;

use of stable isotopes for human metabolic studies, subsequently assayed by neutron activation, to investigate trace elements and their role in nutrition and disease;

in collaboration with Boston hospitals, nuclear medicine applications of the reactor, such as boron neutron capture therapy for brain cancer, high resolution track etch autoradiography to determine boron and plutonium distributions at cellular levels and production of radioisotopes such as gold-198 for cancer therapy, dysprosium-165 for arthritis treatments, chlorine-37 for pulmonary research, phosphorus-32 for numerous biology research application, and many others.

Nearly 100 MIT students, faculty and staff participate yearly in reactor-oriented research, while another 100 approximately are enrolled in courses, seminars and activities that either use the reactor or teach research reactor methods, such as neutron activation analysis. In addition, the reactor was utilized (training, research, demonstrations and/or class visits) by more than 200 students and 28 faculty and staff from 14 other educational institutions, including teaching hospitals. Over 3000 specimens were irradiated for the above purposes during the year.

A much better indication of the scope of some of these activities may be achieved by noting the titles of, or consulting, the papers[14-28] prepared by MIT authors for the above-mentioned symposium[13].

MIT is prepared to assist the Commission further in this present rule-making process.

Sincerely yours,

Otto K Harling

Otto K. Harling, Director
Nuclear Reactor Laboratory

OKH/gw

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2) J.B. Gehret, Jr., "Thermal-Hydraulic Aspects of the Use of Low Enriched Uranium Fuel in the MITR," Master's Thesis, Department of Nuclear Engineering, MIT (January 1984).

3) A. Travelli, "RERTR Program Activities Related to the Development and Applications of New LEU Fuels," *Proceeding of the International Symposium on The Use and Development of Low and Medium Flux Research Reactors*, Cambridge, Massachusetts, (October 1983).

4) L.G. Miller, *et al.*, "Extended Life Aluminide Fuel for University Research Reactors," *ibid*.

5) Letter from J.C. Ebersole, Chairman ACRS, to N.J. Palladino, Chairman NRC, dated June 18, 1984.

6) V. Gilinsky, "Shifting to Non-Explosive Fuels for Research Reactors," remarks before Japan Atomic Energy Research Institute at International Meeting on Reduced Enrichment for Research and Test Reactors, Tokai-mura, Japan (October 24, 1983).

7) Memorandum from J.E. Zerbe, Director, NRC Office of Policy Evaluation, to J. Ahearne, NRC Commissioner, dated March 1, 1983.

8) "Critical Dimensions of Systems Containing U-235, PU-239 and U-233," Report TID-7028, USAEC, Division of Technical Information (June 1964).

9) "Nuclear Proliferation Factbook," Environmental and Natural Resources Policy Division, Congressional Research Service, Library of Congress (September 1977).

10. "Nuclear Proliferation and Safeguards," Office of Technology Assessment, Washington, DC (1977).

11. E.L. Zebroski, "Relative Diversion Exposures of High Enrichment Uranium: Relation to University Research Reactors," presented at American Nuclear Society Special Session on the Use of Low Enrichment Fuel in Research Reactors, New Orleans, Louisiana (June 4, 1984).

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DOCKET NUMBER PR-50 (80)
PROPOSED RULE
(49 FR 27769)

'84 OCT 19 A11:37

From the desk of...
NANCY TAMARIN

To whom it may concern:

I am writing in support of your proposal to convert 31 nuclear reactors in our country to low-enriched fuel.

Sincerely,

Nancy Tamarin
1551 Colman Ct
L A Ca. 90024

Acknowledged by card 10/22/84 pa

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(77)

DOCKETED
OCT 19 1984
DOCKETING & SERVICE BRANCH
SECY-NRC

SAFEGUARD the environment for future generations by immediately cleaning up waste dumps and by strengthening the Environmental Protection Agency (EPA).

We support your proposal to convert 31 nuclear reactors around the country to low-enriched fuel which cannot be used in an atomic weapon.

Highly enriched uranium fuel can be used in an atomic weapon. The risk of nuclear weapons proliferation must be reduced. USA has not taken sufficient steps to control nuclear weapons. We are not afraid of U.S.S.R. They have experienced massive death from war and they want arms control. U.S. lives off people at war and continually perpetrates & perpetuates WAR.

EULA M MC NABB
5521 RICHMOND
DALLAS TX 75206

DALLAS, TX

U.S. arms industry demands WAR to rid the world of old weapons and create a demand for new weapons. This is very hazardous in the age of nuclear weapons. U.S. is obviously avoiding arms control.

U.S. Nuclear Regulatory Commission
Docketing & Service Branch
Secretary of the Commission
Washington D.C. 20555

Acknowledged by card 10/22/84

105

DOCKET NUMBER
PROPOSED RULE PR-50 (85)
(49 FR 27769)

UNIVERSITY OF VIRGINIA
DEPARTMENT OF NUCLEAR ENGINEERING AND ENGINEERING PHYSICS
NUCLEAR REACTOR FACILITY
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
CHARLOTTESVILLE, VA 22901

84 [illegible] 24 P2:41

October 19, 1984

DOCKETING & SERV
BRANCH

Telephone: 804-924-7136

Secretary of the Commission
Attention: Docketing and Services Branch
U.S. Nuclear Regulatory Commission
Washington, D. C.

Dear Sir:

It is our belief that the proposed rule to require the conversion of university reactors from high enriched uranium (HEU) to low enriched uranium (LEU) is unnecessary and that its approval may have an adverse effect on our nation's ability to produce in future years the required number of well-educated nuclear engineers. Our contention is based both on the present adequate level of security provided for university and test reactors, and on the probable catastrophic effect of this conversion on the educational community, taking into consideration the presently diminished status of nuclear engineering among the engineering disciplines. Each of these points will be briefly developed below.

I. Security: Every NRC licensed nonpower reactor facility has recently submitted to the NRC an upgraded security plan. These security plans were developed to address the risk of diversion and, in most cases, have been approved by the Commission. One would believe that approval of these plans by the NRC would indicate a level of confidence in the effectiveness of the security plans that would not justify further extraordinary measures.

In testimony before the ACRS subcommittee and before the House Committee on Science and Technology which reviewed the proposed rule, NRC representatives stated that they know of no identifiable threat concerning the diversion of fuel from university facilities. It was further stated that, for terrorist groups to collect enough enriched uranium and initiate the difficult and time consuming process of constructing a crude nuclear weapon, they would have to steal fuel from "several" facilities. Some witnesses indicated that "several" means more than two. It seems very unwise for the NRC to propose a rule that, by some estimates, will cost the U.S. Government between 10 and 20 million dollars when there is no identifiable security threat and when, for a diversion to be successful, an adversary group would have to attack two or more facilities simultaneously.

II. Effect on Nuclear Engineering Education: In the past several years much has been said about the crisis in engineering education. This crisis is usually expressed as an increased demand by students for

Acknowledged by card 10/25/84 pa

engineering degrees, in excess of the faculty growth rate. Yet another facet of the crisis in engineering education is the obsolescence of teaching equipment in engineering laboratories. Both of these aspects place university administrators under tremendous pressure to find resources for additional faculty and up-to-date equipment. These pressures are particularly great in the so-called high tech areas of computer science, electrical engineering, robotics, etc.

On the other hand, the crisis in nuclear engineering is due to a decrease in enrollment, for there is the perception among some of the public that the nuclear industry is dying. Many nuclear engineering departments are consequently finding themselves in a particularly vulnerable position. A request by a nuclear engineering department head for special funds to affect a conversion of his reactor to LEU, to cover a fuel shipment, for a facility change to accommodate a new core, or for additional manpower to prepare documents for a licensing change, and perhaps even for legal costs to handle a contested application, may not be well received by the University administration. As a result, such a request would likely lead to the curtailment of university nuclear engineering programs, in favor of the presently more popular programs. In testimony before a subcommittee of the House Committee on Science and Technology on September 25, 1984, Professor Forrest Remick, who is on the faculty of the Pennsylvania State University and a member of the ACRS, stated that he believed that "many of the University reactors would close if the proposed rule is enforced," thus crippling the associated nuclear engineering departments.

In summary, we believe that the university reactors, and the research and educational programs they promote, are a valuable resource to the country. Their future should not be jeopardized by an NRC rule which has no strong justification in fact and which many believe, will not accomplish its intended purpose.

Yours truly,

T G Williamson

T. G. Williamson, Professor
Dept. of Nuclear Engineering
and Engineering Physics

Robert Udo Mulder

R. U. Mulder, Director
UVA Nuclear Reactor Facility

DOCKET NUMBER PROPOSED RULE PR-50 (81)
(49 FR 27769)

OCT 24 P2:17

DOCKETING & SERVICE BRANCH

OFFICE OF THE PRESIDENT
CAMBRIDGE, MASSACHUSETTS 02139

19 October 1984

Secretary of the Commission
Attention: Docketing and Service Branch
U.S. Nuclear Regulatory Commission
1717 H Street, N.W.
Washington, D.C. 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49 FR 27769)

Gentlemen:

In response to the Federal Register notice of July 6, 1984 (49 FR 27769-27772), the Nuclear Reactor Laboratory of the Massachusetts Institute of Technology submitted a letter on October 19, 1984, to the Secretary of the Commission commenting on the above proposed rule (10 CFR 50.64).

We are writing in support of the principal conclusions of that letter, specifically:

1. Should the proposed rule be adopted, an exemption of the type envisaged in the proposed rule will be necessary for the MIT Reactor if it is to avoid shutdown and irreparable damage to its related research and educational programs.
2. The MIT Reactor cannot be converted to low enrichment uranium (LEU) with fuels of the type now available or expected to become so within the next five years.
3. Further detailed study will be necessary to determine whether a continuing exemption will be required when and if suitable high-density LEU becomes available, which we understand to be unlikely until 1989 or later.
4. If such studies indicate that high density LEU can be utilized in the MIT Reactor without significant penalty in

Acknowledged by card 10/25/84 pd

performance and if funding is provided to defray all conversion costs, MIT would be willing to convert to LEU fuel. We must emphasize that substantial costs associated with a conversion could not be borne by MIT and would probably force a reactor shutdown. It should also be pointed out that costs from extensive litigation in public relicensing hearings are part of conversion costs if such hearings were to be required. Currently, there are no indications that such public relicensing hearings would not be required if MITR-II were converted to a new fuel technology.

The Institute is most certainly in accord with the goals that underlie the proposed rule and is pleased to offer to the Commission its cooperation and assistance in helping to resolve the issues related to minimizing the risk of diversion of highly enriched uranium from research reactors.

Sincerely yours,

Paul E. Gray
President

Kenneth A. Smith
Associate Provost and
Vice President for Research

PEG/mmd

DOCKET NUMBER
PROPOSED RULE PR-50 (86)
(49 FR 27769)

CNS

DOCKETED
USNRC

'84 OCT 24 P2:40

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Executive Board
Paul C. Warnke
Chairman of the Committee
James F. Leonard
Chairman of the Board
Ruth Adams
Richard Barnet
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R. Admiral Thomas Davies
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Townsend Hoopes
Nancy Ignatius
Betty Lall
Stanley Resor
Robert D. Schmidt
Adele Simmons
Louise Mead Walker
Stanley Weiss
Adam Yarmolinsky
Anne H. Cahn, Director

October 22, 1984

Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: HEU Conversion Rule (19 Federal Register 27769)

Dear Sir:

I am writing to you on behalf of the Committee for National Security, a public interest organization concerned with defense policy, to express strong support for the proposed rule that would require domestic research reactors to convert from the use of Highly Enriched Uranium (HEU) to Low Enriched Uranium (LEU), which, if stolen or diverted, could not be used directly to make an atomic bomb.

The proposed rule is consistent with long-standing U.S. policy discouraging use of HEU worldwide. Foreign research centers have expressed considerable reluctance to convert their reactors if U.S. reactors are not convered. U.S. conversion will show that the U.S. takes seriously the problem of nuclear weapons proliferation.

The proposed rule is prudent in light of the rise in terrorism worldwide and the risks to national security of a terrorist group obtaining weapons-grade material. The proposed conversion will be at U.S. government expense, as opposed to the cost of increased security that would be necessary at sites retaining HEU.

Conversion to LEU would not affect reactor performance. Many successful conversions have already taken place, such as at the University of Maryland's campus reactor. Conversions should be promptly carried out with no exemptions. Shifting to LEU will remove one of the major motivations for public intervention regarding these reactors.

Thank you for your consideration,

Cordially,

Anne H Cahn
Anne H. Cahn
Director

The Committee for National Security
2000 P Street, NW • Suite 515 • Washington, DC 20036 • 202-833-3140

Acknowledged by card. 10/25/84 [illegible]

DOCKET NUMBER
PROPOSED RULE PR-50 (88)
(49FR 27769)

DOCKETED
USNRC

'84 OCT 25 A10:38

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

MEMO

October 22, 1984

From: Richard D. Rogge
32010 Watergate Court
Westlake Village, CA 91361

To: Docketing & Service Branch
Office of the Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Enclosed for your consideration please find my Statement regarding the use of weapons-grade uranium fuel in domestic research reactors.

[illegible]

Acknowledged by card. 10/25/84 pl

NUMBER
RULE PR-50
(49FR 27769)

(100)

AMERICAN NUCLEAR SOCIETY
555 North Kensington Avenue, LaGrange Park, Illinois 60525 USA
Telephone (312) 352-6611 Telex 254635

31 P1:21

October 22, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555
Attn: Docketing and Service Branch

Dear Mr. Secretary:

Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

References:

1. E. L. Zebroski, EPRI, "Relative Diversion Exposures of HEU: Relation to University Research Reactors," presented to the ANS 1984 Annual Meeting, New Orleans, LA, June 3-8, 1984.
2. A. F. DiMeglio, TRTR, "Conversion of Domestic Research and Test Reactors to LEU Fuel," presentation before U.S. House Subcommittees on Energy Development and Applications and Energy Research and Production, September 25, 1984.
3. "ACRS Report on Proposed Rule for Limiting the use of HEU in Domestic Research and Test Reactors," Letter: J. C. Ebersole to N. J. Palladino, June 18, 1984.

The American Nuclear Society (ANS) would like to comment on the subject proposed NRC rule, published in the Federal Register (No. 10 CFR, Part 50), Vol. 49, No. 131, July 6, 1984, pp. 27769-72.

The ANS has been following the NRC activities concerning the Highly-Enriched to Low-Enriched (HEU/LEU) Conversion issue. Our past president, Milton Levenson, expressed a number of serious concerns in a letter to the NRC chairman on March 19, 1984. The chairman of the ANS Education Division, John W. Lucey, also addressed the NRC chairman on May 23, opposing the issuance of the proposed rule. On June 11, I sent Dr. Palladino a copy of a paper by Edwin L. Zebroski (Reference 1), in which he concluded that the diversion risk is minimal for non-power reactors. I suggested in my letter that a more systematic and thorough analysis of these risks would be prudent before issuance of the proposed rule.

In this correspondence the ANS has examined in detail many of the potential problems and risks that the HEU/LEU Conversion rule would pose. The following comments and recommendations summarize the consensus of the ANS organizational bodies, divisions, and individual members knowledgeable of, and/or concerned with, the HEU/LEU Conversion issue.

Acknowledged by card 11/1/84 pd

Comments:

1. Education is one of our highest national priorities because of its relevance to U.S. progress and security. Research and test reactors are of major importance in assuring an adequate supply of professionally trained workers for the essential fields of nuclear engineering, nuclear physics, nuclear chemistry, and activation analysis. The proposed rule would weaken nuclear engineering academic programs already diminished due to inadequate research support.

2. Licensed research and test reactors are an important source of short-lived isotopes for medical research and diagnosis. Reactor shutdowns would likely result from application of the proposed rule, due to the protracted, expensive and uncertain legal procedures that relicensing may require. (See No. 6 below). These shutdowns would probably lead to the cancellation of many teaching, scientific, and medical programs. Shutdowns would not only affect programs at the university or center where the reactor is located, but those of many other universities which have access to, and also use these reactors.

3. While feasibility of HEU/LEU conversion was demonstrated at Argonne for some reactors, the required technology for other reactors is still undemonstrated. Further, LEU fuels for intermediate power reactors, developed in the Argonne program, have not been tested under highly stringent or long-term conditions as the existing HEU fuels have. Also, reload to constant power but reduced flux, a likely outcome of conversion, can significantly affect important programs in radioisotope production, nuclear physics, and activation analysis.

4. In Reference 1, Zebroski points out that (a) the U.S. research and test reactors pose a very low diversion risk; (b) future conversion of overseas reactors (if encouraged by conversion in the U.S.) would not materially affect the risks associated with nearly 20 tons of HEU already exported; and (c) the relative risks, benefits, and social impacts of fuel changes in domestic non-power reactors have not been studied thoroughly.

5. A. F. DiMeglio presented the views of the National Organization of Test, Research and Training Reactors (TRTR) to a joint subcommittee hearing of the U.S. House of Representatives (Reference 2). He emphasized that HEU/LEU conversion of U.S. non-power reactors would not set an adequate example to overseas operators, and quoted a letter from P. von der Hardt, chairman of the European TRTR:

   > "The impact on overseas reactors would therefore be limited to installations below 5 MW which, as in the United States, consume only a minor fraction of the total HEU in circulation."

Hardt concluded that the rule's expressed hope that the U.S. conversion may encourage similar action abroad "appears to be premature."

6. In the proposed rule the NRC requests comments on the concept of "generic envelopes of safety limits," and also on the extent that the economics of conversion should influence NRC actions. We believe that, due to both the significant core changes the conversion would require for many reactors, and the virulence of intervenor groups, it is likely that relicensing after conversion may lead to lengthly and expensive public hearings with unpredictable results. It is sobering to recall the recent decision of UCLA to withdraw its application for license renewal and to decommission its facility after four years of relicensing hearings at an estimated cost to UCLA of $500,000. There are few facilities which could afford such legal expenses and many reactor shutdowns will likely occur. We feel that it would be unrealistic to believe that this outcome could be prevented by involving generic envelopes.

7. The NRC also requests comments on the possiblity that a license amendment may not be required. For the reasons given in Item 6 we believe that licence amendments will be required. In this context, in its recent report to the NRC (Reference 3), the Advisory Committee on Reactor Safeguards foresees the possibility of hearings with public intervention, and recommends that the NRC evaluate whether these hearings "are serving their intended function effectively."

Recommendations

Because of the above considerations, the ANS consensus opinion is that the proposed HEU/LEU conversions of research and test reactors should not take place and, thus, the proposed rule should not be enacted.

We understand that the NRC is charged with protecting the health, safety and well-being of the general public in all aspects of the use of nuclear energy. In the proposed rule, however, the Commission may be interpreting its function in a narrow sense, to hastily achieve a goal of unclear usefulness. By pursuing this goal, the NRC may be responsible for the diminution of the teaching and research capabilities of U.S. universities in the life, physical, natural and engineering sciences and may have misinterpreted its mandate to the nation.

If the NRC still decided to issue the rule, it is essential that before enactment, a systematic and thorough analysis be made of the relative risks of diversion from non-power reactors, and of the relative benefits and social impacts of the conversion. These social impacts include, not only the direct cost of conversion, but also relicensing burdens to facilities, including litigation and loss of overhead funds for the staff involved in relicensing procedures,

Sincerely,

Jm Hendrie

Joseph M. Hendrie, President
American Nuclear Society

cc: ANS Board of Directors
N. J. Palladino
O. J. DuTemple

United States Department of State

Washington, D.C. 20520

BUREAU OF OCEANS AND INTERNATIONAL
ENVIRONMENTAL AND SCIENTIFIC AFFAIRS

DOCKETED
USNRC

'84 OCT 26 A9:10

October 23, 1984

DOCKET NUMBER
PROPOSED RULE PR-50 (90)
(49FR 27769)

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Dear Mr. Chilk:

The Department of State's views on the relationship between the NRC's proposed rule on domestic conversion of research reactors and U.S non-proliferation policy are contained in Ambassador Kennedy's letter of January 13, 1984 to Chairman Palladino, a copy of which is enclosed.

In addition, I would like to offer the following comment on one important aspect of the proposed rule.

The Department of State believes that the criterion for conversion should be changed. In the proposed rule, the wording now reads:

> "Under the proposed rule, non-power reactors would be required to use LEU fuel unless there is a demonstration that the facility's unique propose cannot be accomplished without the use of HEU."

While the "unique purpose" criterion may be satisfactory for future research and test reactors, we believe that it is not suitable for assessing existing reactors; and that a different standard should be incorporated in the regulations. While the Department of State believes that licenses should not be issued for new university research reactors designed to operate on HEU, we believe that the situation is different for the existing stock of reactors which were built at a time when concerns about the use of HEU were not in the forefront of public consideration as they are today. A more reasonable formulation for existing reactors would be as follows:

Mr. Samuel J. Chilk
Secretary of the Commission,
U.S. Nuclear Regulatory Commission.

Acknowledged by card. 10/29/84 pd

> "Under the proposed rule, non-power reactors would be required to use LEU fuel unless there is a demonstration that the facility's unique purpose cannot be accomplished without the use of HEU or that conversion to LEU would impose an undue technical or economic penalty on the reactor operators or users. This rule would apply only to non-power reactors which require fuel reloads."

The reason that our suggested version of the rule does not apply to non-power reactors with lifetime cores is that we do not believe that there are any substantial non-proliferation benefits associated with conversion of these reactors. Existing non-power reactors with lifetime cores do not add to commerce in highly enriched uranium. Furthermore, adoption of the above standard would mean that conversion of domestic reactors would be subject to criteria similar to those now used for foreign research reactors.

Sincerely,

James B. Devine

James B. Devine
Deputy Assistant Secretary

Enclosure:
As stated.

DEPARTMENT OF STATE
AMBASSADOR AT LARGE
WASHINGTON

January 13, 1984

Dear Mr. Palladino:

Thank you for your letter of December 2, 1983, concerning NRC policy on the use of high-enriched uranium (HEU) in NRC-licensed domestic research reactors and Commissioner Gilinsky's views on that subject. Commissioner Gilinsky has not communicated with me on this matter, so I cannot comment on his views. However, I am happy to comment on the thrust of the approach described in your letter.

The Department of State continues its strong support for the RERTR program. It is meeting with considerable success abroad and many of our trading partners have expressed appreciation for U.S. willingness to assist in developing the reduced enrichment fuel and the accompanying conversion program. While I would not suggest that the pursuit of the program domestically would have significant effect on the success of the program abroad, it could have some marginal benefit in demonstrating United States direct interest in pursuit of the program. The concerns and purposes behind our program abroad, of course, are linked to our overall non-proliferation efforts, and this effort will continue whatever the decision may be in respect to the domestic program.

The proposed rule for conversion of domestic research and test reactors which calls for replacement of spent HEU fuel with low enriched fuel, "if such action would be technically feasible with existing fuel technology at the time of refueling, and unless the licensee shows that the unique purposes of the project could not be achieved without using HEU fuel", would be compatible with the criteria used for establishing conversion feasibility and schedules in cooperation with foreign reactor operators.

I appreciate the opportunity to comment.

Sincerely,

Richard T. Kennedy

The Honorable
Nunzio J. Palladino,
Chairman,
Nuclear Regulatory Commission.

RERTR

111

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(98)

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RHODE ISLAND ATOMIC ENERGY COMMISSION
Nuclear Science Center
South Ferry Road
Narragansett, R.I. 02882-1197

DOCKETED

'84 OCT 31 A11:14

October 23, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Docket 50-193
License R-95

Gentlemen:

The Rhode Island Atomic Energy Commission is pleased to submit its comments concerning the proposed rule to limit the use of high enriched uranium (HEU) in its reactor.

The Rhode Island Atomic Energy Commission agrees with the goals of the proposed rule; namely, acceptable diversion risk. However, it believes that through its security plan and its control of fresh fuel, the risks of diversion from its facility of significant amounts of HEU is already acceptable. The Rhode Island Atomic Energy Commission agrees with and endorses the comments on the proposed rule submitted by the National Organization of Test, Research and Training Reactors dated October 24, 1984.

The Rhode Island Atomic Energy Commission operates an intermediate level research reactor which, considering its power level, supports a relatively large activity in neutron spectroscopy directed towards research in nuclear physics and solid state physics. For this research, maximum beam port neutron flux level and energy distribution is essential. Conversion of the reactor to low enriched uranium (LEU) fuel will result in a decrease of flux level by about 10% and a change in distribution of about 15%.

The seriousness of this flux loss may be demonstrated by pointing out that the spectroscopy group at the Rhode Island Nuclear Science Center has recently spent two years designing and building new beam port plugs which through special techniques will increase the flux available for their experiments by 10%! From the standpoint of utilization, conversion to LEU represents a step backwards since flux loss of this magnitude seem to have been brushed aside as not important enough to provide an exemption from the necessity to convert to LEU.

The Rhode Island Atomic Energy Commission is also deeply concerned with licensing problems, including public hearings, which may arise because of mandated conversions. In this regard, we are aware of material being circulated (copy attached) by groups very active in the recently terminated UCLA hearings. While fully supporting public participation in significant licensing activities, we believe that a technique should be devised for preventing license intervention if and before conversions are mandated.

For these reasons, the Rhode Island Atomic Energy Commission is opposed to the proposed rule.

Very truly yours,

A. Francis DiMeglio

A. Francis DiMeglio
Director

AFD:cd

Enclosure

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

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Kevin Gillis
REPRESENTATIVE TO THE
STUDENT BODY PRESIDENTS' COUNCIL

CAMPUS ACTIVITIES OFFICE
SANTA CRUZ, CALIFORNIA 95064

Augest 23, 1984

URGENT

Dear Student Body President:

As you may know there is a non-power nuclear reactor which uses weapon grade uranium (highly enriched uranium- HEU) on your campus. The Nuclear Regulatory Commission (NRC) is presently considering a regulation requiring all nuclear research reactors to convert from HEU to LEU (low enriched uranium) which is non-weapon-grade.

The Student Body Presidents' Council of the nine campus University of California (UCLA and UC Santa Barbara have HEU reactors) strongly supports conversion due to the unique proliferation hazards involved. Our Council has passed the enclosed resolution and we encourage your student government to pass a similiar resolution and to write a short letter in support of HEU conversion to the NRC.* The last date for public comment is September 4th.

I have enclosed an information packet to assist you in writing the letter to the NRC. Please share this information with your Graduate Student's Association. I welcome correspondence on this or related issues.

Sincerely yours,
Kevin Gillis
Kevin Gillis
Chair Social Responsibilities Committee

*Send letter to:
Attention: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SPECIAL ATTENTION--- Letters must be received by the NRC by September 4th!

Associated Students of the University of California
DAVIS • BERKELEY • SAN FRANCISCO • SANTA CRUZ • IRVINE • RIVERSIDE • LOS ANGELES SANTA BARBARA • SAN DIEGO

STUDENT BODY PRESIDENTS' COUNCIL

RESOLUTION

Supporting the Proposed Rule by the Nuclear Regulatory Commission on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

WHEREAS, 31 non-power nuclear reactors are licensed in the United States to use highly enriched uranium (HEU)- 25 are owned by universities including one at UCLA and one at UC Santa Barbara, 5 are owned by private corporations and 1 is owned by the U.S. government; and

WHEREAS, highly enriched uranium can be used without further significant processing and without extensive expertise to build nuclear weapons; and

WHEREAS, the security level at these facilities especially at those on university campuses are not sufficient to even moderately protect from a threat of theft; and

WHEREAS, the threat of terrorism is rapidly escalating world-wide and HEU could sell for over $100,000 per kilogram on the black market; and

WHEREAS, the United States government has spoken out around the world for the reduction of HEU, while at the same time the U.S. exports about 600 kilograms annually (the most in the world) and has not made an effort to limit the almost 500 kilograms of HEU within the U.S.; and

WHEREAS, the reduction of HEU within the U.S. may provide an example and incentive for other nations to emulate thus reducing the danger of international terrorism; and

WHEREAS, the low enriched uranium (LEU) fuels can be used without significant reduction in performance or research potential; now, therefore, be it

RESOLVED, that the Student Body Presidents' Council supports immediate conversion from HEU to LEU internationally and especially within the United States and that the rule must allow no exemptions if it is to accomplish its goal of enhancing national and international security.

8/18/84
KJG

SAMPLE LETTER

Here is a sample letter which could be sent to the NRC. It should be shortened, expanded, or revised as desired.

Attn: Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

I am writing to support conversion of all nuclear reactors which use highly enriched uranium.

This material, which can be used in an atomic weapon, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were carried out.

Conversion of these reactors and removal of the weapons-grade fuel can be a signal to the rest of the world that the U.S. takes seriously the problem of nuclear weapons proliferation. This proposal could help to discourage the use of HEU fuel worldwide.

But in order to be effective, it must be non-voluntary and it must be promptly implemented.

Thank you for your consideration.

Sincerely, etc.

HELP REDUCE THE USE OF WEAPONS GRADE URANIUM

The Nuclear Regulatory Commission has proposed a new rule which would require about 30 nuclear research reactors to convert from highly enriched uranium fuel (HEU) to low enriched fuel (LEU). HEU is weapons grade and could be used, if stolen or diverted, to make an atomic bomb. LEU could not.

The NRC's proposed rule would reduce the threat of theft of weapons grade material and would encourage a reduction in the use of HEU around the world. If implemented, it could be one of the most significant achievements in nuclear non-proliferation in recent years.

Although conversion would not affect reactor performance, nuclear reactor operators are strongly opposed to it, largely because of the increased public attention to their facilities, many of which are situated, relatively unknown, on college campuses. The reactor operators are well organized and will attempt to defeat the proposal or "water down" its provisions.

The NRC has invited public comment on the proposal. Please write a letter. Even a couple of sentences expressing support for the HEU conversion proposal would be very useful.

Additional points which could be made include:

--The conversions should be carried out as soon as possible, not five or ten years from now. Many successful conversions have already taken place, such as at the University of Maryland's campus reactor. The safer LEU fuel is available now.

--The basic reason for conversion is the threat of theft of material which could be used to make an atomic bomb. Therefore no reactors should be exempted from the rule, which is needed to enhance national and international security.

Written comments must be received by September 4, 1984. They should be addressed to the Secretary of the Commission, Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing & Service Branch.

For more information:

Committee to Bridge the Gap
1637 Butler Avenue, #203
Los Angeles, CA 90025
(213)478-0829

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(93)

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RHODE ISLAND ATOMIC ENERGY COMMISSION
Nuclear Science Center
South Ferry Road
Narragansett, R.I. 02882-1197

'84 OCT 29 P12:47

DOCKETING & SERVICE
BRANCH

October 24, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

The National Organization of Test, Research and Training Reactors (TRTR) is pleased to submit its comments concerning the proposed rule to limit the use of high enriched uranium (HEU) in its reactors. The 31 or so non-power reactors (NPR) which will be affected by the proposal to convert to low enriched uranium (LEU) fuel are all members of TRTR. TRTR conducted its annual meeting in August, 1984 and these comments represent the consensus developed at that meeting.

The operators of the 31 reactors fully support the goals of no undue risk of diversion of enriched uranium from their facilities. However, they do not believe that the achievement of acceptable risk requires the abandonment of the use of HEU, which will be the result if the proposed rule is adopted. TRTR, therefore, opposes the adoption of the proposed rule for the reasons which follow.

The risk of diversion of HEU from the NPR facilities (and therefore, the necessity for the proposed rule) has not been adequately assessed. Zebroski (1) has examined the relative diversion risks from many different types of facilites which utilize HEU and he concludes that the group of reactors targeted for conversion present the lowest diversion exposure. This, coupled with the fact that these reactors utilize only 10% of the HEU used in domestic research and test reactors, means that conversion of the 31 non-Department of Energy reactors does not significantly affect domestic diversion risk.

Acknowledged by card 10/30/84
pk

The Nuclear Regulatory Commission itself has stated that ....."currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public." The proposed rule, therefore, will reduce an already acceptable risk which in itself is only a small fraction of the overall risk. A broad view of the risk, in perspective to other closely related risks, suggests that the risk reduction benefit for conversion of the targeted reactors is rather small and the total costs are rather high.

TRTR believes that this attempt to reduce the risk to zero of the diversion of any amount, however small, of HEU has precluded discussion of alternatives to the abandonment of HEU.

An obvious alternative to LEU is appropriate security. In most facilities an appropriate level of security already exists and it can be extended to additional facilities if necessary. Recall that the security plans for non-power reactors were evaluated by the Nuclear Regulatory Commission against a diversion risk within the last few years and approved. In fact, protection of non-power reactors against acts of vandalism, theft of equipment and injuries to personnel will in general provide the security level necessary to protect against diversion of HEU.

The Nuclear Regulatory Commission staff has testified on several occasions that there has been no evidence of a theft or diversion attempt at any research reactor. In addition, the Nuclear Regulatory Commission has stated that the intelligence agencies have not identified any threat against such facilities. Nevertheless, the credence given to the remote possibility of successful diversion simultaneously from the number of reactors necessary to obtain material sufficient for a weapon, sets the seeds for future panic. If credence is given by authorities to instant bombs from insufficient material, then future panics are likely to be an unfortunate by-product. The rule may unintenionally and indirectly contribute to a real increase in public risk because of panic.

Another alternative to the proposed rule is engineering fixes, the best example being the use of long-life HEU cores. Already, 18 of the 31 reactors have true lifetime cores with 12 of these having inventories less than 5 Kg. Using the high uranium density fuels being developed by the Department of Energy Extended Life Aluminide Fuel (ELAF) project due to be completed in about one year, more highly loaded HEU fuel elements can be utilized with about double the present burnup limits providing semi-lifetime cores with less than 5 Kg inventory for several more reactors. Because of the longer lifetime of such fuel, fewer elements will be in storage, in the fabrication pipeline and in transit, thereby reducing the proliferation risk in comparison with today's practices.

In testimony on September 25, 1984 before subcommittees of the House Committee on Science and Technology, the Department of Energy stated that it had no interest in funding the conversion of lifetime cores. The Department of State stated that it agreed that converting lifetime cores did not make much sense at this time.

An examination of the 31 reactors targeted by the proposed rule reveals the following:

Lifetime cores	19
Decommissioning announced	1
Currently shut down	1
High performance (conversion technology unavailable)	3
Currently at 70% enriched	2
Total	26

Of the five (5) remaining reactors, several could take advantage of the ELAF programs and operate with in-house inventories of less than 5 Kg.

TRTR believes that the mission of the Reduced Enrichment Research and Test Reactors (RERTR) program has been too finely drawn and has been concentrating on only one aspect of the broad task of reducing the proliferation risk from non-power reactors. In fact, as presently constituted, the program will serve very few facilities as shown by the above statistics and few facilities will survive an across-the-board application of the new fuel technology. TRTR believes that the mission of the Argonne Program should be expanded to study all ways of reducing the proliferation risk at non-power reactors including the design of long-life cores. This redirection of the program will demonstrate the commitment of the United States to maintaining and improving nuclear education and research capability, will allow the United States to regain its lost leadership role in this area and will demonstrate to the international community its dedication to no undue proliferation risk without technical regression.

Another reason given for the proposed rule is that the conversion of domestic reactors will set an example for the international community. TRTR does not believe that the conversion to LEU of a few intermediate power domestic reactors sets the correct example for operators of foreign reactors. In fact, the European non-power reactor community has stated (2) in correspondence to the Nuclear Regulatory Commission that the example being set by the United States is the conversion of its lower power reactors involving only a small fraction of United States HEU traffic, with no conversion of high power level reactors. Comparable conversions overseas will similarily not have a serious effect on HEU traffic overseas. The United States can demonstrate its goodwill towards reduced proliferation risk by arranging for the return to the United States of the more than 10 tons of HEU in spent fuel being stored in Europe.

TRTR is concerned about the use of "generic licensing" as part of the proposed rule. For most reactors, the fuel description is part of the technical specifications: some reactors will require other changes in the technical specifications. If, as a consequence of these changes, a license amendment is required, then a hearing with the opportunity for public intervention is possible. Along with the Advisory Committee on Reactor Safeguards, TRTR believes that before the adoption of a rule which might permit unrestricted intervention ".....the Commission obtain an evaluation of the course, nature, costs and other relevant aspects of previous contested hearings involving non-power reactors to determine if the hearings are serving their intended functions effectively. It may be that the rules regarding hearings involving low power research reactors should be different than those for power reactors". The entire NPR community has been sensitized to the licensing issue because of the recent decision of UCLA to withdraw its application for license renewal after four years of hearings at an estimated cost to UCLA of $500,000. If litigation occurs because of the proposed rule, clearly half of the reactors involved will decommission. TRTR does not believe that generic licensing of a fuel design which has not been tested under abnormal operating conditions is feasible. TRTR recommends that the RERTR program be expanded to qualify fuel element behavior under accident conditions based on the legal criteria used in the UCLA hearings.

Concerning the extent that economics of conversion should influence Commission actions, TRTR believes that in an area where real benefits are minimal and there is already "no undue risk", economic considerations must be paramount. Already RERTR has spent about 35 million dollars: it is estimated that an additional 30 million dollars will be required. Conversion of university reactors is estimated at 12-15 million dollars: conversion of the remaining non-power reactors will require an additional 1-2 million dollars. Clearly, without considering the Nuclear Regulatory Commission and individual facility costs, expenditures are already very high in an area where lower cost alternatives are available for the aversion of risk to the public health, safety and the environment. This is especially true considering the societal costs associated with the proposed rule which will effectively downgrade most reactors and cause the decommissioning of several.

With regard to funding if conversions are mandated by the Nuclear Regulatory Commission, TRTR believes that since these conversions will be based on a change in national policy rather than on some unidentified threat, all conversions should be at federal government expense for all reactors, even those operated by non-federal government organizations. In addition to the direct costs for the new fuel, reprocessing of old fuel and facility modifications, these federal funds should be available for relicensing, including litigation and for lost overhead funds for the facility staff involved in the relicensing procedure.

TRTR urges the Commission not to adopt the proposed LEU rule and pledges the cooperation and support of its membership in developing and implementing alternatives.

Very truly yours,

A. Francis DiMeglio

A. Francis DiMeglio
Chairman, TRTR

AFD:cd

(1) See Attachment 1

(2) See Attachment 2

1786

DOCKET NUMBER
PROPOSED RULE PR-50 (89)
(49FR 27769)

S-L FILM PRODUCTIONS
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DOCKETED
USNRC
'84 OCT 25 A10:37
OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Friends:

We support your proposal to convert thirty-one nuclear reactors around the country to low-enriched fuel which cannot be used in a weapon. In view of the very dangerous situation confronting us with regard to nuclear weapons and the nuclear arms race, your proposal might serve to make the world just a little safer.

Sincerely,

Esther Schiller

Esther and Gerald Schiller

Acknowledged by card.. 10/25/84 pd

DOCKET NUMBER PR-50
PROPOSED RULE (49 FR 27769)

94

SOUTHERN CALIFORNIA FEDERATION OF SCIENTISTS
3425 McLaughlin Avenue, Suite 209
Los Angeles, California 90066

DOCKETED
USNRC

'84 OCT 29 P1:23

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

October 25, 1984

Attn: Docketing and Service Branch
Office of the Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

Enclosed please find the comments of the Southern California Federation of Scientists concerning the proposed HEU conversion rule (49 FR 27769).

Sincerely,

Sheldon C. Plotkin, Ph.D., P.E.
Co-Chairperson

Acknowledged by card. 10/30/84
pl

DOCKET NUMBER
PROPOSED RULE PR-50 (95)
(49 FR 27769)

The First United Methodist Church of West Los Angeles

Rev. Steven Poteete-Marshall, Pastor

1637 Butler Avenue
Los Angeles, Calif. 90025
(213) 473-1285

'84 OCT 29 P1:25

DOCKETING & SERVICE
BRANCH

October 25, 1984

Attn: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir,

I am writing concerning the H.E.U. Conversion Rule (49 Federal Register 27769). I want to express my support for the conversion of all nuclear reactors which use highly enriched uranium.

I am concerned that this material poses an unnecessary threat to national and international security. It makes sense to avoid a disastor by converting the reactors now. I believe that the financial cost is small in comparison to a successful theft of the fuel.

The world often follows our nation's lead. This conversion could help to discourage the use of H.E.U. fuel worldwide.

Thank you for your consideration.

Sincerely,

Rev. Steven Poteete-Marshall

Acknowledged by card. 10/30/84 pd

Nuclear Proliferation: Studies and Strategies for Stopping the Spread of the Bomb

NUCLEAR CONTROL INSTITUTE

1000 Connecticut Avenue, N.W., Suite 406, Washington, D.C. 20036 (202) 822-8444

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(104)

OCT 31 P2:28

October 25, 1984

Secretary of the Commission
United States Nuclear Regulatory Commission
Washington, D.C. 20555

ATTN: Docketing and Service Branch

Notice of Proposed Rulemaking:
Limiting the Use of Highly Enriched Uranium
in Domestic Research and Test Reactors
(10 CFR Part 50)

Dear Sir:

We are writing to express the views of Nuclear Control Institute on the Commission's proposed rule, "Limiting the Use of Highly Enriched Uranium in Domestic and Research Test Reactors," 10 CFR Part 50, published in the Federal Register on July 6, 1984 (49 Fed. Reg. 27769).

We commend the Commission for proposing the rule and concur with the Commission in recognizing the "significance of the proposed rule to the national interest." At the same time, for the purpose of serving that interest more effectively, the Institute has specific recommendations for strengthening the rule to expedite conversion of licensed research reactors from highly enriched to low-enriched uranium fuels and to grant exceptions only in cases in which any benefits clearly would outweigh the risks associated with the fact, as stated in the rule, that "HEU, in appropriate form and quantity, can be used to make an explosive device which can have severe adverse consequences on public health, safety and the environment."

Conversion Schedule

We are concerned that the conversion schedule to which the operators would have to adhere is not, in the current language of the proposed rule, developed in a manner that will promote speedy

Acknowledged by card 11/1/84 pt

PRESIDENT
Paul L. Leventhal

BOARD OF DIRECTORS
Peter A. Bradford David Cohen Rear Admiral Thomas D. Davies, USN (Ret) Denis A. Hayes
Julian Koenig Paul L. Leventhal Sharon Tanzer Leventhal Dr. Theodore T. Taylor Barbara W. Tuchman

compliance. Section 50.64(d)(2) states, "The proposed schedule shall be based upon availability of shipping casks, financial support, and reactor usage. A final schedule will then be determined by the Director of the Office of Nuclear Reactor Regulation."

The Institute recommends that the Commission establish a two-year deadline to complete conversion, subject to exceptions granted only under extraordinary conditions. Operators should be required to submit proposed schedules within six months of the effective date of the rule, not 12 months as currently provided. A decision on scheduling should be made by the Commission within 12 months of the effective date of the rule with the objective of completing conversion within the following 12 months.

With regard to factors affecting the conversion schedule, we believe "reactor usage" should not be among them. Several of the reactors subject to the rule are underutilized and consume fuel at such a slow rate that it would be years before they would be required to convert if all present fuel had to be exhausted first. Further, the smaller reactors have a lifetime supply of HEU on hand and would never be required to convert to LEU if consumption of exisiting fuel were the determining factor.

Nor do we believe "availability of shipping casks" should be a factor in delaying conversion. Since conversion requires the use of casks for only a few days, the Commission, with cooperation from the Energy Department, should be able to coordinate the conversion effort to avoid completely the problem of supplying the necessary casks. (The question of "financial support" as a factor is addressed below.)

The "availability of replacement fuel," in our view, is the only factor that should be considered in developing schedules for conversion to LEU. As the Commission itself notes in the introduction to the proposed rule, "conversion of several non-power reactors from HEU fuel to LEU fuel is technically feasible and, if the goals of the RERTR [Reduced Enrichment for Research and Test Reactors] program are successfully achieved over the next five years, will be technically feasible for almost all the remaining reactors." We agree with this finding and recommend that conversion schedules should be extended beyond two years from the effective date of the rule only for those few reactors for which fuel will not be available within that period.

Unique-Purpose Exception

Sections 50.46(d)(1) and (2) should be amended to require that a request for an exemption from conversion on the grounds of the reactor's unique purpose be submitted within six months of the effective date, as already stipulated, but together with a proposed schedule in the event that the request is not approved. In this way, the Commission would still be able to approve a conversion schedule within the 12-month period recommended above for those reactor operators whose requests for an exception are denied.

Further, we recommend that the decision to grant exceptions should not be left to the sole discretion of the Director of the Office of Nuclear Reactor Regulation. Because of the vital national-security interests at stake in this issue--- both with regard to eliminating bomb-grade nuclear material from campuses and to setting an example for foreign operators--- exceptions should be granted only by a vote of the Commission, and only in cases of legitimate countervailing national interest.

Further, the Commission should strike Section 50.64(b)(3)(i), which would allow a unique-purpose exemption on the basis of "[a] specific experiment or program." The Commission should not grant such exemptions unless the "preponderance" of work done at the reactor requires HEU.

In the event the Commission grants an exemption that permits a delay of or exclusion from the rule, the Commission should require that (1) security at the reactor be substantially upgraded to ensure protection of the HEU on site and (2) that the licensee be require to absorb the full cost of the upgrade. Similiarly, if the Commission decides to downgrade the proposed rule to permit more reactors to continue using HEU than would be the case under present provisions, such licensees should be required to upgrade security at their own expense.

In our view, it is unthinkable to keep weapons-grade uranium in reactors with the lax security as now exists at some sites (see the January 27 testimony of Daniel Hirsch, Committee to Bridge the Gap); if licensees are not required to convert to LEU they must lower to acceptable levels the danger that the HEU presents by improving the security around it. We believe that existing NRC standards for security at licensed non-power reactors, which require only detection, rather than prevention, of unauthorized entry, need to be upgraded substantially for any such facilities that continue to use HEU.

Financial Considerations

The economics of conversion are such that conversion to LEU can be implemented without delay at those sites for which fuel is available. Congress this year appropriated $2 million for this project, a sum representing as much as 40%---and at least 15%---of total conversion costs. In light of this development, and the historical record noted by the Commission of federal support for such undertakings, there is every reason to expect that the conversion will be fully funded by the federal government.

Operator objections on the basis of cost are, therefore, unfounded, especially, as the Commission correctly notes, "Any economic analysis should include estimates of the aversion of risk to public health, safety and the environment." It bears repeating in this context that security measures undertaken in the place of conversion should not be federally funded. Such costs are likely to exceed substantially the costs of conversion.

The Commission raises the legitimate question of whether "the economics of conversion should influence Commission actions." We believe that economies should not influence the Commission's actions. Given the national and international security interests at stake, the costs of conversion would certainly be a small price to pay, even if one uses the cost estimates of the most pessimistic analyses provided by the operators.

Relicensing

A related and equally unfounded objection is that conversion would involve a relicensing procedure which would allow public-interest groups to intervene and attempt to shut the reactors down. In our view, the Commission has included provisions to keep to an absolute minimum the possibility that conversion of non-power reactors would require relicensing. Even in cases in which relicensing were necessary---and it would be only an amendment to an existing license rather than a complete relicensing---the public-interest groups of concern to the operators would have no reason to intervene since they strongly support the proposed conversion and, in fact, will do whatever they can to expedite the process. On the other hand, public-interest groups can be expected to seek a substantial upgrading of security at reactors that are not required to convert and the shutdown of those where security is not upgraded satisfactorily.

Technical Implications

Critics of the rule have also raised questions about the technical implications of the conversion. Some opponents of the rule have claimed that the changeover would adversely affect reactors' research capabilities. However, as Dr. Theodore Taylor of our Board of Directors made plain in his testimony before the Commission on January 27, the universities already have restricted themselves by limiting the power of their reactors. If they want to compensate for the loss in neutron flux caused by the conversion, he pointed out, they can increase the power level of the reactors.

International Implications

Another objection raised is that any positive impact of the conversion---that is, removing HEU from circulation and thereby encouraging foreign governments to take similar steps---is minimized because the HEU in question at licensed facilities represents only about 15% of the total in U.S. reactors. This argument also misses some of the fundamental points of the Commission's rule. First, foreign governments have expressed a willingness to support the RERTR program but, understandably, would like to see the U.S. impose such restraints upon itself before expecting other countries to do so. And, although the HEU in question does represent only a small fraction of the U.S. total, the proposed rule represents the first tangible commitment by the U.S. to get its own house in order. Once the proposed NRC rule takes effect, efforts can be made to have the Energy Department, which controls the remaining HEU, consider the conversion of its test reactors. In the meantime, HEU will have been removed from low-security environments such as college campuses. This removal would represent a significant step in increasing international security, for it would eliminate an extremely inviting and vulnerable target for terrorists.

In conclusion, the Institute strongly supports the Commission's proposed rule with the changes recommended above. The rule provides a means by which the national interest can be served with the most minimal expenditure and inconvenience to the parties involved.

Sincerely,

Daniel Horner

Paul Leventhal
President

Daniel Horner
Issues Director

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(109)

UNION CARBIDE

UNION CARBIDE CORPORATION
MEDICAL PRODUCTS DIVISION
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TELEPHONE NUMBER: (914) 351-2131

'84 -1 A11:35

October 26, 1984

U. S. Nuclear Regulatory Commission
Secretary of the Commission
Washington, DC 20555

Attn: Docketing and Service Branch

Subj: Comment on Proposed Rule

Gentlemen:

The Nuclear Regulatory Commission published for comment a proposed rule which will limit the use of highly enriched uranium (HEU) in domestic Research and Test Reactors in the July 6, 1984 Federal Register Vol. 49, No. 133, pp. 27769 thru 27772. The Union Carbide Research Reactor (UCNR) located at the Sterling Forest Laboratory, in Tuxedo, New York, uses HEU fuel and the conversion of this fuel to low enriched uranium (LEU) could be required by this proposed rule.

The operating characteristics of a reactor that is fueled with LEU will be different from those of an HEU fueled reactor and, since all of the existing UCNR operating parameters are based on an HEU core and since all of the products and services currently provided by this reactor were developed in an HEU core and since the financial base of operation has been established from experience with an HEU core, the conversion of the UCNR from HEU to LEU fuel will have a significant impact on all aspects of the operation of the facility. We expect the same situation exists at most other operating facilities that use HEU fuel. Therefore we offer the following comments concerning this proposed rule.

Acknowledged by card 11/1/84 pd

The NRC policy to limit the quantity of HEU in use is intended to reduce the risk of theft or diversion of HEU for unauthorized purposes. The NRC states that "HEU in appropriate form and quantity can be used to make an explosive device". The proposed rule to require research reactors to convert to LEU fuel is intended to implement that policy.
A recent risk assessment[1] which examines the relative risk of having research reactor HEU fuel used for making an explosive device reveals that the research reactor community presents the least exposure for diversion of HEU. Futhermore it points out that the quantity and form of HEU that is normally present in a research reactor facility is insufficient to manufacture a basic device (crude bomb) even if the equivalent resources of a U. S. National Laboratory were employed in its manufacture. This situation was corroborated by testimony of other knowledgeable people in the hearings on this subject that were conducted by the NRC Commissioners, the ACRS and the House Committee on Science and Technology. Given this information it can be concluded that the proposed rule will have little or no impact in carrying out the stated policy.

Higher risks for the diversion of HEU exist outside of the research reactor community. These have been identified recently during the many public discussions and hearings that were precipitated by this proposed rule. It appears imprudent and inconsistent to apply this rule only to the small NRC licensed, Research Reactor community. It is also apparent that a large amount of HEU is in storage in the form of irradiated fuel, most of which is overseas, which poses a greater risk for diversion than the HEU that is in immediate use. It seems that a more prudent expenditure of resources would be to return this HEU material that is in storage to the U.S. and recycle it into the system that is more secure. The cost of removing this high risk will be orders-of-magnitude less than the approximately $30 million already spent on the RERTR program.

[1] Testimony of E. Zebrosky before the ACRS hearing on HEU/LEU conversion 06/12/84.

We note that the NRC hopes to encourage the conversion of foreign reactors as a result of the proposed rule. Foreign operators and governments are inclined to view the U.S. as one entity and therefore may not percieve this rule as encouragement to follow because most of the HEU in domestic use is in facilities operated by DOE and it will be exempt from the requirements of the proposed rule.

The above general comments notwithstanding, several technical issues remain unresolved which will have an impact on reactor core characteristics, operating parameters, license limits and costs. These issues conflict with the basic premise of the RERTR LEU conversion program which is to avoid "significant changes to existing facilities or significant decrease in performance characteristics of the reactors". It is important to consider the purpose or raison d'etre of a reactor as much as whether it is technically feasible and safe to operate with LEU fuel when assessing the impact of conversion.

The low density, high enriched fuels currently in use have been proven to be reliable over more than 30 years of normal operation in numerous reactors and under accident conditions as demonstrated in the SPERT and BORAX tests. Normal performance of the lower density LEU fuels has been modeled in computer codes and verified but performance under accident conditions has not been verified with experimental data. In the areas of safety and reliability the presently used aluminide and oxide HEU fuels are excellent. The low density HEU fuel matrix provides interstitial space for the fission products without resulting in fuel plate swelling when yielding greater than 50% burnup in service. The LEU fuels accommodate the low enrichment via much denser fuel loading. This denser matrix has much less space for fission product volume increases and therefore it could be more prone to swelling. The denser uranium fuels will have a different thermal conductivity. These phenomena could alter the retention of the fission product source term and they should be fully understood before wholesale conversion to LEU is mandated.

The neutron flux energy spectrum in LEU cores may alter control rod worths, the effective delayed neutron fraction and other important characteristics, all of which could change operating margins or require revision of operating limits. The percieved benefit of the LEU conversion issue is to reduce the risks to the public due to HEU diversion. Are we trading risks here? The perceived diversion risk is supposed to be reduced with LEU but the price is the substitution of a relatively untested fuel for a proven, accident tested fuel.

The IAEA LEU Core Conversion Guidebook (IAEA-TECDOC-233 App. F-1 MTR Benchmark Calculations) predicts a hardened neutron energy spectrum and an approximate 10% reduction in the thermal neutron flux after LEU conversion. These predictions were generally confirmed in the Ford Reactor conversion to LEU. Our reactor is basically a thermal neutron source for producing radioisotopes and performing nuclear irradiation services. A 10% reduction in thermal neutron flux will result in a 10% reduction in productivity. The "harder" flux will also reduce the quality of our major service irradiation work, neutron transmutation doping of electronic grade silicon. These consequences of conversion to LEU cause a "significant decrease in performance" of the UCNR.

The major radioisotope products that are manufactured in the Sterling Forest Facility are separated from the fission products of U-235. The hardened flux spectrum, manifested by the reduction of thermal flux and the increase in epithermal flux, will result in an increase of Pu-239 (U-238, n-γ reaction) in our radioisotope production waste. If the Pu-239 content of the waste were deemed to exceed 10 CFR 61 limits there is no disposal method for such waste currently available. If Union Carbide had no approved method or disposal site for this waste we could not continue operations.

Over the last five years the UCNR has made progress in increasing operating efficiency by improved fuel management while using HEU fuel. The useful life of each fuel element has been extended by increasing the burnup per element. We also have been considering higher U-235 loading per fuel element and the addition of burnable poisons to further increase fuel life. As the high density uranium-aluminum technology proceeded we saw more opportunities, utilizing HEU, to reduce our reactor operating costs and increase our overall productivity. These opportunties disappear if the high density technology is taken up by LEU conversions.

Conversion to LEU will have other negative economic consequences which will be realized more immediately. Even if the out-of-pocket conversion cost is subsidized by the Government, we can foresee significant indeterminate costs which will be required for amending license conditions. Changed reactor operating characteristics will require safety analyses, technical specification changes, revised operating procedures and revised training and requalification programs. License amendment proceedings are often open-ended, unpredictable affairs. This cost will be compounded because the technical staff involvement in these licensing issues will be a distraction from the usual, more productive work.

After a conversion were accomplished, we anticipate increased reactor operating costs due to reduced thermal neutron flux levels, higher fuel fabrication costs and increased fuel reprocessing costs. This is particularly important at our Sterling Forest Reactor because of its function in radioisotope production. We have estimated that the overall cost of isotopes production could increase approximately 20% after LEU fuel were substituted for HEU fuel. The details of this anticipated cost increase were provided to the NRC in previous correspondence during hearings on this rule.

There exists, in addition to the above mentioned economic impact, an impending major risk for incurring legal costs if the LEU conversion rule will allow opportunities for public hearings under 10 CFR 51. There is little incentive to carry out long and costly litigation in the hearing process particularly when an intervenor's ultimate objective is to delay operation indefinitely. The university reactor community has stated that many reactors would cease operation in such circumstances. The long-term societal cost of this eventuality is real considering that a large and increasing source of energy in this country is from nuclear energy. These university research reactors are vital to maintain and improve the technology that will be needed in this industry.

Although we agree with the objective of the proposed rule we believe that it will do little to accomplish it. There appear to be more effective and less costly steps that can be taken immediately to reduce the risk of diversion of HEU from research reactor facilities. We propose the following actions to achieve this purpose:

(1) Limit the amount of fuel at any reactor site to a bare minimum to sustain reliable operation. It is especially desirable to eliminate as much as possible the amount of fresh fuel by dispensing it from a central, secure respository as it is needed at each facility.

(2) Reduce the domestic and international traffic of HEU through the use of fuels that have longer useful life. This could be accomplished through higher density HEU loadings containing burnable poisions. The RERTR program has made this technology accessable now without going to extremely high densities.

(3) Require that irradiated spent HEU fuels be returned to the U.S. within some minimum time that is dictated by safe transport and cask availablity.

This proposed rule is going to place a burden on the research and test reactor community that is disproportionate to the relatively low risk that these facilities present for diversion of HEU for the ultimate purpose of manufacturing an explosive device. We believe that it should not be implemented.

Very truly yours,

James J. McGovern
Business Manager
Radiochemicals

JJMcG:js

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(111)

OSU

The Ohio State University

Nuclear Engineering Program
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206 West 18th Avenue
Columbus, Ohio 43210
Phone 614 422-8519

'84 A11:57

October 26, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Docketing and Service Branch

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

We are pleased to submit our comments concerning the proposed rule to limit the use of highly enriched uranium (HEU) in domestic non-power reactors (NPRs). The views expressed herein form a consensus opinion of those individuals listed at the close of this letter, and do not necessarily represent an official policy position of The Ohio State University as a whole.

Those of us who are examining the proposal to convert domestic NPR facilities from HEU to low enrichment uranium fuel (LEU) oppose the adoption of the proposed rule in its present form. The reasons for our opposition follow.

Basis of the Proposed Rule

We support the concept of reducing undue risk of diversion of highly enriched uranium from its intended use. However, it is unclear whether such a concern necessitates the conversion of all domestic NPRs from HEU to LEU fuel.

The proposed rule states that "the Commission considers that currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public." This is stated both in the Summary and in Supplementary Information. We affirm our belief that the safety of domestic NPR operations is adequate and does not pose an undue risk to public health and safety. Nothing in the record indicates that past or current HEU-fueled NPR operations contradict this statement. The Commission staff has stated that the various intelligence agencies have not identified any threats which would reduce the current margin of safety inherent in existing security plans. First, the domestic NPR facilities currently targeted for conversion contribute very little to total diversion risk. Schleicher [1] states that the total mass of HEU currently under Euratom Safeguards is 14,400 kilograms. Marshall [2] points out that through 1982 total U.S. exports of HEU amounted to 23,590 kilograms, distributed to 43 nations. The total authorized mass of HEU fuel for 23 domestic NPRs is 390.9 kilograms, which represents 2.7% of the Euratom total and 1.7% of the export total.

Acknowledged by card 11/1/84 pd

Further, many domestic NPRs contribute very little or no HEU to the total material traffic. At least 18 reactors have long-life cores, with 12 of these having an authorized HEU quantity of less than 5 kilograms. In addition, non-domestic NPRs with lifetime cores will not be affected by restricted HEU export policies. The proposed rule in its present form will result in an undue discriminatory measure against domestic NPRs with lifetime cores. In effect, the rule will impose domestic policy more restrictive than that applied to foreign HEU users. This goes beyond the goals of the original policy of restricting international traffic of HEU.

It is our understanding that the purpose of the Reduced Enrichment Research and Test Reactors (RERTR) program was not to address conversion of domestic NPR facilities to LEU fuel, but to aid in reducing international use of HEU. The Commission should exercise caution in using RERTR program results as a vehicle for formulating policy directed towards domestic facilities prior to issuance of RERTR program final recommendations.

Proposed Rule May be Premature

If the intent of the Commission is to require submission of conversion schedules upon issuance of the proposed rule in final form, we believe that such requirements would be premature. First, much of the basis for the proposed rule lies in the results of the RERTR program. This program is still in progress. Also, the Commission has stated that possible development of "generic" envelopes and safety limits is being evaluated. These envelopes and limits are intended to aid in the relicensing of facilities after conversion to LEU. However, such generic licensing envelopes are still in the development stage. Consequently, it would be inappropriate to require licensees to submit schedules and make commitments.

License Proceedings and Intervention

We are greatly concerned that requiring LEU conversion will permit unrestricted intervention in relicensing proceedings. Even if "generic" licensing procedures are developed, fuel specifications and descriptions are a part of the technical specifications for most reactors. Other reactors may require additional changes in their technical specifications. As a consequence, a license amendment may be required. This opens the possibility of public hearings and general intervention. Thus, prior to adoption of a rule with these consequences, the Commission should evaluate the consequences of such proceedings and determine if steps might be taken to modify the hearing process to avoid unnecessary, costly, and nonproductive litigation.

We consider it unlikely that any "generic licensing" proposals will adequately assure that licensees will not be subject to costly and lengthy litigation brought by determined intervenors. Decommissioning of many NPR facilities vital to maintaining high quality educational and research programs could result. In particular, we hope that any "generic licensing" procedure would include consideration of fuel performance under abnormal operating conditions. Such consideration would reduce the risk of the issuance of the proposed rule placing the viability of many facilities at risk.

Financial and Societal Costs

Conversion costs could total between 12 and 15 million dollars for those reactors targeted by the proposed rule. We understand that in testimony presented before the subcommittees of the House Committee on Science and Technology, DOE officials stated that they have no inclination towards funding conversion of lifetime cores. The Department of State also agreed that such conversions were not reasonable at this time. Funds for LEU conversion were deleted by the House from FY85 DOE budget requests. The RERTR program is funded to help non-U.S. reactors only.

Even if funding at the federal level were available, it is difficult to believe that it would cover anything but the capital costs for fuel procurement, with perhaps a small amount available for technical assistance, facility staff time, etc. This would leave the licensees to bear the costs of facility downtime and the loss of revenue-generating activities, facility modifications (if necessary), core calibration and testing, removed HEU fuel shipment and disposal, and the potentially very large costs associated with relicensing proceedings and litigation. Simply put, many licensees, in particular universities, cannot bear these costs, and would opt to decommission their reactor facilities.

In the Supplementary Information section, the statements are made that "NRC shares the licensees' expressed view that conversion costs should be largely or entire (sic) be financed by the Federal Government. Historically, the DOE and its precedessor agencies have provided significant support to research and test reactor programs. The availability of Federal support will be a key factor considered in determining the availability of LEU fuel and schedules for conversion." Further, former Commissioner Victor Gilinsky has suggested on several occasions that DOE provide conversion funds [3,4]. This has also been the opinion of Chairman Palladino [5]. However, as noted earlier, DOE officials have testified of their reluctance to provide conversion funds, and the House has deleted such funding. Given the past, current, and possible future political climate in Congress concerning matters related to nuclear technology, there appears to be no assurance that conversion funding will be forthcoming. This striking difference of viewpoint between NRC and DOE should be resolved prior to considering issuance of the proposed rule.

We consider the continued operation of NPR facilities vital to the maintenance of high quality educational and research programs. Historically, the U.S. has been world leader in the advancement of nuclear science and technology. This role would be jeopardized if significant numbers of research reactor facilities were forced to decommission due to LEU conversion-related costs and problems. The university environment would be very seriously affected. We believe that "hands-on" experience with an operational research reactor is an important part of the education of students entering the field of nuclear science and technology. A shortage of well-trained engineers exists in the nuclear industry. Obviously, decommissioning of university-owned research reactors would not help this situation. It is possible that, in the name of reducing proliferation risk, the overall risk of nuclear industry activities will be increased due to fewer and less-well trained personnel entering the field as a result of the educational impact of decommissioning university research reactors. As educators and researchers, we believe that the Commission should weigh these downside risks carefully in their consideration of the proposed rule in its present form.

If, after considering all things, conversion is mandated by NRC, and if funding is provided, we believe that such funding should come from the Federal Government, and be available to all affected facilities, even those operated by non-federal government organizations. Further, such a mandate should be based on a change in national policy. Funds should be included to cover costs not only for new fuel, but for removal and disposal of old fuel, facility modifications (if any), core testing and calibration, staff time, and relicensing costs including litigation and lost overhead funds due to redirected staff activities and facility unavailability.

Alternatives to General Conversion

The Commission should consider an alternative to total conversion of all domestic NPRs to LEU fuel. Specifically, those domestic NPRs with lifetime cores should be exempted from converting to LEU. These facilities contribute no material to the total HEU traffic, and generally possess less than a formula quantity of HEU on site. Thus, they contribute very little to the overall total diversion risk.

Summary

Those of us at The Ohio State University who are studying the HEU-LEU conversion question for our research reactor facility believe that the Commission should not adopt the proposed rule in its present form. We extend to the Commission our support in developing and evaluating alternatives that will support the goals of reducing diversion and proliferation risk.

References Cited in Comments:

1. H.W. Schleicher, "Euratom: Non-Proliferation and Safeguards in the 1980's", Proceedings of the International Executive Conference on Non-Proliferation and Safeguards, Mexico City, September 7-10, 1980, pp. 89-96 (American Nuclear Society).

2. E. Marshall, "NRC Targets University Reactors", Science, Vol. 223, March, 1984, pp. 912-913.

3. V. Gilinsky, quoted by Jane Perlet, "Colleges' Uranium Seen As Threat", The New York Times, January 29, 1984.

4. V. Gilinsky, letters to Dr. Edward H. Jennings, President of The Ohio State University, and Dr. Don Miller, Nuclear Engineering Program, 10/2/84, 10/17/84.

5. N. Palladino, letters to Dr. Edward H. Jennings, President of The Ohio State University, and Dr. Don Miller, Nuclear Engineering Program, 12/2/83.

Very truly yours,

Don W. Miller

Don W. Miller
Professor and Chairman
Nuclear Engineering Program

Walter E. Carey

Walter E. Carey
Associate Professor
Nuclear Engineering Program
Director, Radiation Safety Office

Tunc Aldemir
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Joseph W. Talnagi Jr.

Joseph W. Talnagi, Jr.
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Associate Director
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Brian K. Hajek

Brian K. Hajek
Associate Director
Nuclear Reactor Laboratory

JWT:lam

cc: E.H. Jennings, President
D.H. Haenicke, Vice President for Academic Affairs and Provost
J.M. Hollander, Vice President for Research and Graduate Studies
T.L. Sweeney, Associate Vice President for Research and Graduate Studies
D.D. Glower, Dean, College of Engineering
R.F. Redmond, Associate Dean, College of Engineering

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DOCKET NUMBER PROPOSED RULE PR-50 (92)
(49 FR 27769)

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

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ADLAI E. STEVENSON COLLEGE   SANTA CRUZ, CALIFORNIA 95064

'84 OCT 29 A11:55

October 26, 1984

The Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
attention: Docketing & Service Section

RE: HEU Conversion Rule (49 FR 27769)

Dear Secretary Chilk:

Enclosed please find a copy of my statement to subcommittees of the House Science and Technology Committee on the issue of the proposed NRC rule on conversion of research reactors utilizing weapons-grade uranium. I would appreciate the enclosed statement being included in the comments to the NRC regarding the proposed rule.

I would make the following additional points as well:

It has been argued that since kilogram quantities of weapons-grade uranium have supposedly not as yet been stolen from research reactors in this country (although apparently such thefts have occurred from other domestic facilities utilizing HEU, such as NUMEC), there is no demonstrated threat to these facilities warranting replacing their HEU with LEU. Within this counter-argument to the proposed rule appears to be a serious misunderstanding of the concept of threat. The argument relies entirely on the absence of a threat having been carried out to date; however, a threat's inherent danger lies in possible future actions.

All the data (see the attached statement) indicate a rapidly escalating level of terrorist activity--in numbers of incidents, magnitude of casualties, sophistication of methods used, and in the numbers of nuclear incidents. There is thus clearly a threat at present. If the trends continue, the existing threat to these facilities (made much worse in the wake of the attacks on the Iraqi HEU-fueled research reactor) will continue to escalate.

The proposed rule is designed to respond not to past threats, but to the danger of future threats. Conversion, after all, will take several years. One can only hope that the rising lines in the graphs of terrorist incidents do not reach the point of theft of HEU from research reactors and detonation of a clandestine fission explosive before the proposed NRC policy of conversion can be instituted.

Acknowledged by card 10/30/84 pd

Even if the trends were not convincing enough, we must remind ourselves that it only takes one act by one terrorist group to cause unacceptable damage. Terrorists live on the fringe of society. To expect all of these groups to behave within certain limits (e.g., not attempting to steal and use nuclear material), is imprudent. It would be relying on the fringe of society's fringe to act within rational limits. Recent events leave little hope that terrorists will act rationally.

The proposed conversion rule would eliminate the possibility of terrorist groups obtaining a nuclear capability. There seem to be no logical arguments to the contrary because:

- The government will pay for HEU replacement costs.
- The performance of the reactors will be essentially identical with LEU as with HEU.
- An exemption procedure is proposed for those two or three reactors who can make a solid case that conversion would make impossible their unique research.

Any delay or overturning of conversion means a very dangerous situation in the future when these same facilities face the far more dangerous world that appears ahead. The tragedies in Beirut are a powerful reminder of the danger that may result if comprehensive preventive measures against terrorist action are not taken in a timely fashion.

Sincerely,
Stephanie A. Murphy
Stephanie A. Murphy
Nuclear Terrorism Research Projec
Adlai Stevenson Program
on Nuclear Policy

UNIVERSITY OF SOUTHERN CALIFORNIA
UNIVERSITY PARK
LOS ANGELES, CALIFORNIA 90089-1062

DEPARTMENT OF CHEMISTRY
(213) 743-2780

DOCKET NUMBER PR-50
PROPOSED RULE
(49 FR 27769)

(97)

'84 OCT 30 A11:14

October 26, 1984

Docketing and Service Branch
Office of the Secretary
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Sir:

Please consider my enclosed statement concerning the use of HEU in research/training reactors.

Sincerely,

James C. Warf

James C. Warf
Professor of Chemistry

Acknowledged by card 10/31/84 pd

21

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

DOCKET NUMBER
PROPOSED RULE PR-50 (112)
(49 FR 27769)

'84 -1 P2:46

October 26, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

The National Bureau of Standards is pleased to comment on the above subject proposed rule. NBS has carefully studied the proposed rule and respectfully offers the following comments and recommendations.

1. The need for the rule is not supported nor justified by the evidence even from national policy considerations since the proposed rule affects a very insignificant movement of HEU compared to foreign and DOE owned reactors and, therefore, clearly will not set an example for other nations.

2. The impact of the proposed rule has not been properly assessed. As a minimum, the proposed rule should be set aside and an independent comprehensive study undertaken by the NRC to realistically evaluate the following.

   a. The number of research reactors that will be shut down.

   b. True cost-benefit analysis including loss of technical competence.

   c. Effect on nuclear education and training.

   d. Effect on advanced research.

   e. The effect on the development of new, state-of-the-art research reactors and the upgrade of existing facilities.

      In this regard, it has been repeatedly stated by NRC and others, including the RERTR group, that a loss of 10 percent in the quality and magnitude of the neutron flux is insignificant. Far from it, even without the loss of flux quality, a 10 percent loss in magnitude could be very significant. Imagine a reactor that operates 1.2 months of each year producing nothing, yet, the cost of operation remains the same. Fuel costs, manpower costs, equipment and utilities costs, and more important, radioactive materials handling and transportation, radioactive releases, and personnel exposures all essentially remain the same. This is but one of many disadvantages as a result of what is called a small

Acknowledged by card 11/2/84

reduction in flux, which reaffirms the need for a more careful and thorough understanding of the impact of the rule.

3. Alternatives and other approaches in place of the rule have not been properly evaluated or pursued. Among these are:

   a. Encourage voluntary conversion if the cost and impact are demonstrated to be minimal. This apparently has worked for the University of Michigan where their needs could be accommodated by the conversion.

   b. Long-life cores for intermediate size reactors.

   c. Coordinating safeguards programs and controlling HEU inventories. Recently developed safeguards plans have greatly enhanced security at research reactors and their benefits have not been properly evaluated. Similarly, the amount of unirradiated fuel in storage at research reactors has been reduced considerably. A combination of a centralized safeguards information center at NRC where information can immediately be passed on to research reactors and contingency plans activated plus possible further reductions in inventories should be carefully considered.

4. It makes no sense to destroy lifetime cores. There is no reason for converting this class of reactors when no foreign reactor with a lifetime core is being asked to do so. Similarly, it is not in the national interest to downgrade high-performance reactors. On the contrary, this class of reactors should be provided with every opportunity, both technical and regulatory, to expand, upgrade, and optimize in order to continue to conduct world-class research. Only in this way can the United States remain competitive, reverse the decline in world standing, and restore U. S. leadership in nuclear and material research and advanced technology. In this connection, the most recent advanced research reactors have been built not in the United States but overseas. In view of the above, these two classes of research and test reactors should not be included in any LEU rule.

5. The safety and performance of proposed new LEU fuels have not been demonstrated and will not be adequately demonstrated under proposed testing programs. Current HEU fuels have proven reliability and performance over many decades at scores of reactors. New LEU fuels should be proven at least to the same reliability levels under both normal and accident conditions prior to general use.

Clearly, based on these few comments, and there are numerous others, the proposed rule leaves a lot to be desired and further careful, deliberate, and critical examination as to its wisdom is necessary. The paramount question for the NRC and the research reactor community should be what is best for the United States and the American people. The United States should always be in the forefront of nuclear science and technology. We must strive for the best nuclear research, the best nuclear education, and the best in high technology. To achieve this, we must have the best facilities. Already the United States has fallen behind Europe in many important areas of research because of lack of facilities. One such area is cold neutron research. For years the Europeans have had cold neutron sources designed and installed into several of their reactors permitting extensive research on metals, polymers, and biological materials. The National Academy of Sciences in a recent report (the Seitz Committee Report) prepared for the Director of OSTP listed as the number one national priority the development of cold neutron sources at research reactors. The NBS reactor is the only licensed research reactor and one of only two in the Country that could accommodate such a source.

In conclusion, it seems clear that the proposed rule will have a far reaching and very likely adverse impact on the role and effectiveness of research reactors in the United States. Its adoption, therefore, should be seriously questioned.

Sincerely,

Robert S. Carter

Robert S. Carter
Chief, Reactor Radiation Division

DOCKET NUMBER
PROPOSED RULE PR-50 (108)
(49 FR 27769)

'84 NOV -1 A10:30

BRANCH

Gentlemen 10/27/84

The use of highly enriched nuclear fuels in research reactors, many of which have markedly easy access, places weapons quality enriched uranium in dangerously exposed positions.

Conversion of these reactors to permit use of low enriched fuels would minimize risks of terroristic or other diversion to weaponry without significantly limiting the functions of the research reactors or production of medical & research isotopes.

Abraham Spindel

MR ABRAHAM SPINDEL
9127 OLIN ST
LOS ANGELES, CA 90034

VAN
PM
29 OCT
1984

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Docketing & Servicing Branch
~~Secretary~~ of the Commission
U.S. Nuclear Regulatory Comm.
Washington, D.C.
20555

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Acknowledged by card 11/1/84 pd

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UNIVERSITY OF DAYTON, WILMINGTON COLLEGE, CAPITAL UNIVERSITY

(107)

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

October 29, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555
Docketing & Service Branch

Re: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir,

As the co-director of OhioPIRG, a statewide organization concerned with energy, consumer, and environmental issues, I am writing on behalf of the organization and our members to urge the conversion of all nuclear reactors which use highly enriched uranium.

Currently, 25 universities, five corporations, and one government agency run non-power reactors with the high-enriched fuel, which is actually weapons-grade material. Why should we allow the constant risk of the theft of this fuel that can be made into atomic bombs by terrorist groups? It is in the interests of U.S. and world security to convert each and every one of these reactors now (not five or ten years from now) to low-enriched uranium.

The low-enriched (LEU) safer fuel is available now, and the reactor at the University of Maryland already has undergone a successful conversion, as well as many other reactors across the country.

The operators of these reactors will not convert without an NRC requirement to do so, and unless all HEU reactors are converted, the theft of weapons-grade fuel will remain a nightmare reality.

OhioPIRG urges the enactment of the proposed conversion rule immediately. It will serve as a signal to the rest of the world that the United States is serious about the problem of nuclear weapons proliferation, and it will mean a great step forward in protecting our national security.

Thank you for your consideration.

Sincerely,

Dan Jaffee
OPIRG Co-Director

Acknowledged by card. 11/1/84
pd

DOCKET NUMBER PR-50
PROPOSED RULE (49 FR 27769) (99)

4620 Knox Road
College Park, Md. 20740
29 Oct. 1984

'84

Secretary of the Nuclear Regulatory Commission
Washington, D.C. 20055, Attn. Docketing and Service Branch

This will refer to the proposed rule 10 CFR Part 50 titled "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors" published in the Federal Register Vol. 49, No. 131, 6 July 1984. My concern is primarily the impact on University training and research programs. In recent years, a number of these programs have limited their activities; some have become a part of other departments and a few have disappeared. This academic contraction has stemmed from a reduction in student enrollment and financial support; this probably reflects the uncertainty in nuclear reactor sales, the vocal and well organized antinuclear effort, and unfavorable environmental publicity, e.g. Three Mile Island.

The proposed change in fuel enrichment would entail financial expense, increased staff burdens, reduced reactor operation, and delays in plans. The probable licensing changes are likely to open the way for those intervenors whose aim is strictly antinuclear, with litigation and delays as tactics, rather than genuine public safety. In addition, changing the core of a reactor which was carefully designed for a particular objective is very likely to decrease usefulness and add safety problems. All this could further discourage professors and college administrators, and result in a loss of more nuclear engineering offerings.

These nuclear education activities have been quite productive as indicated by the attached summary of papers before the American Nuclear Society (ANS) and of graduates. About 35 schools, 200 to 300 professors, have been contributing ca 20% of the papers to the ANS Transactions; Universities with reactors have been the most productive. The graduates have helped staff commercial activities as well as related Naval and other efforts. Loss of University programs would hurt all these employers and the nuclear industry in general.

My interest stems from a long association with the nuclear field. This has included initiating the nuclear engineering program and the nuclear reactor facility at the University of Maryland and serving as Nuclear Reactor Director for about 10 years. This was when the reactor had highly enriched fuel; I am not now involved with the University's reactor. Most of my recent research has been with Cf 252 neutrons at Argonne, Los Alamos, and Oak Ridge; however, this work resulted from the Maryland reactor. Based on this experience, I feel that diversion of irradiated fuel is very unlikely. It seems that protection of unirradiated fuel could be by limiting the amount at a facility, by special personnel selection, and other administrative measures.

My conclusion is that possible risks of diversion of weapon grade material from University reactors can be made acceptably small. Consequently, to me, the money spent on refueling, possible loss of usefulness, disenchantment of staff, probable litigation, time delays, and possible damage to programs does not justify the enrichment change proposed. This is a personal opinion and not necessarily that of the University of Maryland.

Very truly yours,

Dick Duffey

Dick Duffey

Acknowledged by card. 11/4/84

Transactions of American Nuclear Society, Vol. 39, p.53, Nov. 1981, San Francisco

University Papers in ANS *Transactions*, with Enrollment and Degrees, *Dick Duffey (Univ of Maryland), Peter F. Wiggins (U.S. Naval Academy)*

Statistics on nuclear engineering course offerings, enrollment, degrees, and papers published in the ANS *Transactions* were presented in 1966 at the University of West Virginia and in later publications.[1-3] More recently enrollment and degree data have been compiled by the U.S. Atomic Energy Commission, the Energy Research and Development Administration, and the U.S. Department of Energy.[4,5] We have updated our tabulation of papers in the *Transactions* (Annual and Winter Meetings) for U.S. and Canadian schools (Table I); the number of nuclear engineering staff is included.[6]

Although many journals publish nuclear engineering research, the *Transactions* of ANS is a favorite and reflects graduate school activity. Review of Table I reveals that the principal contributors are schools with well-identified nuclear engineering departments, sizable staffs, and a research reactor. The size of the average nuclear engineering staff of the schools with many papers is about ten. Some 20 of the 183 schools contributed more than 70% of the papers. These top 20 schools are essentially the same as those of five years ago, with some change in order.[3]

The papers in the *Transactions* from schools are in Table II. Since about 1960, the time that nuclear engineering programs began graduating significant numbers, schools have contributed about one-fifth of the papers. The effect on papers of meeting location (hence travel expense) can be noted; the number of papers correlates roughly with the number of PhDs. The number of contributions in the *Transactions* from non-North American schools is small.

Enrollment and degree data are in Table III. Since nuclear engineering has often been under older departments, identification of graduates and enrollment has been somewhat uncertain, and sources of information give different numbers. Nevertheless, BS degrees have increased steadily. Most early nuclear engineering programs were initiated at the graduate level. Later, BS programs were added; the motivation has been (a) industrial demand for BS graduates, (b) a necessity to feed graduate programs, and (c) a need for more administrative influence on distribution of both school budgets and staff positions, which is often weighted toward departments with undergraduate enrollment (i.e., more students). MS degrees seemed to have peaked a few years ago; the PhD graduates have decreased maybe one-third since 1970. This decrease probably relates to the demand and salary for BS and MS graduates and the reduced financial support for graduate students, e.g., limited fellowship programs. Studies show the number of foreign students receiving PhD degrees in engineering rose from 10% in 1968 to ~35% in 1978 (Ref. 6); for nuclear engineering, the number of foreign students went from 22 to 37% from 1973 to 1978 (Ref. 4). These doctoral figures and the foreign percentage probably portend difficulties in staffing faculty and industry in the United States.

In conclusion, universities continue to contribute much to the *Transactions*, and nuclear engineering is becoming increasingly identified at the BS level. The data on papers and degrees, particularly PhDs, deserve serious attention by those in government and industry concerned with graduate student support.

TABLE I

Papers in ANS *Transactions* by Universities 1958-1980 with Latest Nuclear Engineering Staff

School	Papers	Staff
1. MIT R	312	21
2. Illinois R	235	--
3. RPI R	202	12
4. Calif. LA R	155	--
5. Wisconsin R	145	16
6. Calif. Berkeley R	139	10
7. Florida R	132	12
8. Tennessee	131	9
9. Michigan R	124	13
10. Georgia Tech R	110	16
11. Washington R	102	9
12. Missouri (Columbia) R	96	7
13. Penn State R	95	14
14. Maryland R	92	5
15. Purdue R	87	12
16. Arizona R	85	12
17. Virginia R	80	13
N. Carolina St. R	80	7
19. Stanford	69	--
20. Iowa St. R	67	9
21. Texas R	62	--
22. Kansas St. R	61	8
23. Oregon St. R	59	9
24. Columbia	58	--
25. Northwestern	57	--
26. Cincinnatti	55	--
27. New Mexico	43	--
28. Texas A & M R	41	7
VPI R	41	4
30. Cornell R	40	4
31. Toronto	38	--
32. Lowell Inst. T R	29	--
Carnegie R	29	--
34. Calif. Inst. T	28	--
35. McMasters R	27	--
36. U. S. Naval Academy	26	--
37. Ohio St. R	25	5
Princeton	25	--
39. Catholic	22	--
Calif. S. Barbara	22	--

School	Papers	Staff
Utah R	22	--
42. Howard	21	--
43. Buffalo R	19	--
44. New York	18	--
Calif. Davis	18	--
46. Oklahoma	15	3
47. Rochester	13	--
Notre Dame	12	--
Brigham Young	13	--
Calif. Irvine R	13	--
Missouri (Rolla) R	13	5
52. U.S. Air Force I.T.	11	--
U.S. Navy P.G.	11	--
Kentucky	11	--
55. Pittsburgh	10	--
Louisiana St.	10	6

Others

1 School with 9 papers
2 " " 8
6 " " 7 "
5 " " 6 "
6 " " 5 "
8 " " 4 "
17 " " 3 "
27 " " 2 "
56 " " 1 "

R - Research Reactor at school

Total 183 schools with
3877 papers

TABLE II

Papers in ANS *Transactions* Through 1980

Transactions			Meeting Location	Total Papers	Papers from Schools	% from Schools
Year	Vol.	No.				
1958	1	1	Los Angeles	196	5	2.6
		2	Detroit	194	15	7.7
1959	2	1	Gatlinburg	229	16	7.0
		2	Washington	174	7	4.0
1960	3	1	Chicago	215	14	6.5
		2	San Francisco	399	40	11.8
1961	4	1	Pittsburgh	207	9	4.3
		2	Chicago	244	21	8.6
1962	5	1	Boston	327	51	15.6
		2	Washington	266	33	12.4
1963	6	1	Salt Lake City	237	29	12.2
		2	New York	320	40	12.5
1964	7	1	Philadelphia	237	35	14.7
		2	San Francisco	383	53	13.8
1965	8	1	Gatlinburg	358	54	15.7
		2	Washington	395	65	16.5
1966	9	1	Denver	361	61	16.9
		2	Pittsburgh	356	74	20.8
1967	10	1	San Diego	472	94	19.9
		2	Chicago	381	67	17.6
1968	11	1	Toronto	491	108	22.0
		2	Washington	340	50	14.7
1969	12	1	Seattle	469	96	20.5
		2	San Francisco	658	142	21.6
1970	13	1	Los Angeles	507	92	18.1
		2	Washington	525	99	18.8
1971	14	1	Boston	582	109	18.7
		2	Miami	463	102	22.0
1972	15	1	Las Vegas	647	160	24.8
		2	Washington	432	125	29.0
1973	16		Chicago	376	108	28.8
	17		San Francisco	612	129	21.1
1974	18		Philadelphia	394	83	21.2
	19		Washington	511	126	24.6
1975	21		New Orleans	575	119	20.7
	22		San Francisco	843	171	20.2
1976	23		Toronto	638	142	22.3
	24		Washington	502	104	20.7
1977	26		New York	621	155	24.9
	27		San Francisco	865	165	19.1
1978	28		San Diego	663	95	14.3
	30		Washington	695	109	15.7
1979	32		Atlanta	653	144	22.0
	33		San Francisco	759	155	20.4
1980	34		Las Vegas	726	130	17.9
	35		Washington	514	76	14.9
			TOTAL	20,952	3877	av. 18.5

TABLE III

Nuclear Engineering Graduates and Enrollments

Year	Enrollment			Degrees		
	BS.	MS	Ph.D.	BS	MS	Ph.D.
1960	596	673	149	53	157	18
1961	607	495	251	66	202	16
1962	742	544	335	71	224	27
1963	473	632	403	72	229	36
1964	694	624	471	125	312	62
1965						
1966		627	519	145	294	122
1967	863	739	619	167	326	137
1968	1011	749	809	251	320	148
1969	1117	671	663	315	386	154
1970	1194	544	549	424	413	182
1971	1235	912	709	446	414	171
1972	1316	911	659	536	436	161
1973	1332	1018	622	663	482	128
1974	1445	1224	602	628	486	129
1975	1813	1446	656	529	475	101
1976	1946	1329	583	648	469	148
1977	2160	1168	577	788	564	121
1978	2084	1064	586	777	487	110
1979	1882	968	638	746	453	117

1. DICK DUFFEY, "University Presentations in *Transactions* of American Nuclear Society," *Trans. Am. Nucl. Soc.*, 14, 56 (1971).

2. DICK DUFFEY, "Nuclear Engineering at Colleges and Universities," *Eng. Education*, 63, 8 (1973).

3. DICK DUFFEY and P. F. WIGGINS, "University Paper in the *Transactions* of American Nuclear Society," *Trans. Am. Nucl. Soc.*, 23, 71 (1976).

4. "Nuclear Engineering Enrollment and Degrees," Reports WASH 1228 (72) (Nov. 1972), WASH 1228 (73) (May 1973), WASH 1228 (74) (July 1974), ERDA-76 (75) (Sep. 1975), PDA-76-102 (July 1976), ERDA-77-102 (July 1977), DOE/IR-0011 (1978), and DOE/IR-0053 (1979).

5. JUNE CHEWNING, U.S. Department of Energy, Personal Communication (Nov. 1980).

6. "Engineering College Research and Graduate Study," *Eng. Education*, 71, 6 (1981).

1815

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DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(96)

STUART M. TURNANSKY, M.D.
1803 MISSION STREET #518
SANTA CRUZ, CALIFORNIA 95060

DOCKETED
USNRC

'84 OCT 29 P1:26

DOCKETING & SERVICE
BRANCH

Secretary of the Commission
U.S. Nucleur Regulatory Commission
Washington, D.C. 20555

Dear Sir:

I am writing to support the conversion of all nucleur reactors which use highly enriched uranium. As you are aware, I am sure, the use of HEU fuel presents a clear and present danger as HEU is weapons grade and could be utilized to produce nucleur fission bombs, while LEU could not. Further, as conversion would not affect reactor performance, if conversion could be implemented it could be one of the most significant achievements in nucleur non-proliferation in recent years. I strongly urge you to carry out this conversion of all nucleur reactors which use HEU, in order to avoid a possible calamity of unprecedented magnitude. Thank you.

Sincerely,

Acknowledged by card. 10/30/84 pk

·126

DOCKET NUMBER PR-50
PROPOSED RULE
(49 FR 27769)

(101)

UNIVERSITY OF MISSOURI-ROLLA

Nuclear Reactor Facility
Nuclear Reactor
Rolla, Missouri 65401
Telephone: (314) 341-4236

'84 OCT 31 A11:17

October 29, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

We, at the University of Missouri-Rolla Reactor, wish to comment on the Proposed Rule published in the Federal Register (49 Fed. Register 27769). The Nuclear Regulatory Commission states in the Rule's Summary that

> "... currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public."

We agree with the Commission that the above statement is appropriate to make. We also strongly support efforts by the Commission to reduce the risk of a theft or a diversion of highly-enriched uranium (HEU) fuel. However, we do not believe that the conversion of domestic non-power reactors to low-enriched uranium (LEU) fuel will, as the Commission suggests,

> "... encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use."

Past experience, for example with the Breeder Reactor technology, has shown that a unilateral U.S. decision has little effect (if any) on the other nations.

We expect that if the proposed rule is promulgated it will have a serious impact on our facility and thus will affect this University's educational capability. Even if federal funding were made available to us for the acquisition of LEU fuel we might still have to face significant licensing proceedings, including extended public hearings as some recent events have shown. Few universities, if any, can afford the costs of long and protracted litigation proceedings. Licensing costs, whether direct or indirect, in terms of manpower and potential delays may force us to close down our facility. However, this is not in the best national interest. We need to maintain strong progress in terms of scientific and technological research and innovation. In addition, the reactor facilities are needed for the training and education of students with nuclear engineering and power backgrounds. Currently, nuclear utilities have a shortage of well-trained personnel.

At the rate at which the uranium-235 has been consumed in our reactor, which has been approximately one gram per year, we contend that we have a lifetime's worth of fuel remaining. To convert from the current HEU fuel to LEU would be a needless waste of natural and financial resources and would necessitate a premature shipment of fuel.

We therefore urge the Commission to withdraw its proposed rule to convert non-power reactors to LEU fuel.

Sincerely,

Milan Straka
Reactor Manager

MS:gf

an equal opportunity institution

Acknowledged by card 11/1/84 pd

127

DOCKET NUMBER PR-50 (102)
PROPOSED RULE (49 FR 27769)

UNIVERSITY OF MISSOURI-ROLLA

Nuclear Engineering Department

Rolla, Missouri 65401

Telephone: (314) 341-4720

'84 [illegible]

October 29, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Sirs:

The Nuclear Engineering faculty of the University of Missouri-Rolla wish to express their concern about the proposed rule (49FR27769) regarding the conversion of certain nuclear reactors from highly-enriched uranium to low-enriched uranium.

Although the proposal sounds honorable in principle, we fear that it may jeopardize the continued operation, and perhaps the future, of some reactors, including our own. In addition, from what we have learned of the House Committee on Science and Technology subcommittee hearings held on the matter in Washington, D.C., on September 25, 1984, it seems the U.S. Department of Energy is no more than a reluctant partner in this matter.

Even as the rule is presently proposed, we feel that the Reactor Facility staff (and also the campus administration) might be drawn into lengthy and expensive public hearings and other such re-licensing activities. Possibly the facility could even be shut down for some period of time while the matter is being resolved. This would have strong adverse impact on the primary missions of the facility, which are education, training and research.

In 1981 a special ad hoc committee assigned by the Chancellor concluded that the nuclear reactor is the main educational laboratory for the nuclear engineering students and as such should continue to be supported by the administration. The reactor is also used by a number of faculty from various departments in support of their valuable research. The facility has been utilized to provide training for approximately 120 utility reactor operators. In the next four months approximately 40 more utility personnel will be trained using this reactor.

Thus, the temporary closing of the facility or its premature decommissioning will further diminish the educational capability of the state of Missouri and of the nation in the vital area of nuclear energy.

The UMR Reactor has a virtual lifetime supply of fuel (4800 grams of uranium-235), which is less than a "formula quantity". The uranium-235 has been consumed at the rate of about one gram per year since the reactor went into operation in December of 1961. The fuel portion is in the chemical form of U_3O_8 dispersed in an aluminum matrix.

Acknowledged by card. 11/1/84 pd

For these and other reasons, we conclude that the proposed rule is not needed for the UMR Reactor, nor for many of the other non-power reactors that are involved. Thus, the rule should not be put into effect.

Sincerely,

N Tsoulfanidis
N. Tsoulfanidis, P.E.
Chairman and Professor

D Ray Edwards
D. Ray Edwards, P.E.
Professor

Albert E. Bolon
Albert E. Bolon, P.E.
Associate Professor

A Kumar
Arvind Kumar
Assistant Professor

Gary E. Mueller
Gary Mueller, P.E.
Assistant Professor

gf

cc: Senator Danforth
Senator Eagleton
Congressman Emerson
Congressman Young

128

DOCKET NUMBER
PROPOSED RULE PR-50 (103)
(49 FR 27769)

UNIVERSITY OF MISSOURI-ROLLA

School of Mines and Metallurgy

Office of the Dean

104 Mining Building
Rolla, Missouri 65401
Telephone (314) 341-4153

'84 [illegible] AM :50

October 29, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

We wish to comment on the Proposed Rule as published on July 6, 1984 in Federal Register (49 Fed. Reg. 27769). We, at the University of Missouri-Rolla, agree with the NRC Commission that (as stated in the Rule's Summary) "... currently licensed non-power reactors using HEU fuel are operated without undue risk to the health and safety of the public." We also strongly support efforts by the Commission to reduce the risk of a theft or a diversion of highly-enriched uranium (HEU) fuel. However, we believe that the risk of diversion of HEU from the domestic non-power reactor facilities has not been sufficiently evaluated and that emotional rather than technical arguments prevail in the current discussions about the conversion to low-enriched uranium (LEU) fuel.

We disagree with the Commission that "The reduction in domestic use of HEU fuel may encourage similar action by foreign research reactor operators, and thereby reduce the amount of HEU fuel in international use." Past experience, for example with the Breeder Reactor technology, has shown that a unilateral U.S. decision has little effect (if any) on the other nations.

We expect that the proposed rule, if promulgated, will have serious financial consequences for many colleges and universities (like the University of Missouri) and thus will affect this nation's scientific and technical educational capabilities. Many universities and colleges may not have the funding needed to convert their reactors to LEU fuel. Even if federal funding were made available to these institutions for the acquisition of LEU fuel there still might be significant licensing considerations involved, including extended public hearings as some recent events have shown. Few universities, if any, can afford considerable costs of long and protracted litigation proceedings. Licensing costs, whether direct or indirect, in terms of manpower and potential delays may force us to close down our facilities. However, this is not in the best national interest. We need to maintain strong progress in terms of scientific and technological research and innovation. In addition, the reactor facilities are needed for the training and education of students with nuclear engineering and power backgrounds. Currently, nuclear utilities have a shortage of well-trained personnel.

Acknowledged by card 11/1/84 pl

We also believe that the proposed rule is premature since its success largely depends on results of a research program (Reduced Enrichment for Research and Test Reactors Program) which should prove (or disprove) the ability of new LEU fuels to replace existing HEU fuels. However, this program is still underway.

At the rate at which the uranium-235 has been consumed in our reactor, which has been approximately one gram per year, we contend that we have a lifetime's worth of fuel remaining. To convert from the current HEU fuel to LEU would be a needless waste of natural and financial resources and would necessitate a premature shipment of fuel.

In summary, we believe that the costs for the conversion to LEU fuel far outweigh (in the global sense of nuclear non-proliferation) the marginal benefits. Therefore, we urge the Commission to withdraw its proposed rule to convert non-power reactors to LEU fuel.

Sincerely,

Don L Warner

Don L. Warner, Dean
School of Mines and Metallurgy

DLW:gf

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(105)

Associated Students of the University of California

DAVIS • BERKELEY • SAN FRANCISCO • SANTA CRUZ • IRVINE • RIVERSIDE • LOS ANGELES • SANTA BARBARA • SAN DIEGO

'84 NOV -1 A10:09

STUDENT BODY PRESIDENTS' COUNCIL
926 J St. Room 522
Sacramento, Ca. 95814

October 29, 1984

Att: Docketing and Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re: HEU Conversion Rule (49 Federal Register 27769)

Dear Sir:

On September 25, 1984 the Energy Development and Applications Subcommittee and the Energy Research and Production Subcommittee of the House Committee on Science and Technology held a public hearing on the NRC's proposed rule to require conversion of all nuclear research reactors from highly enriched uranium to low enriched uranium. The University of California Student Body President's Council, which represents the 141,000 students of the nine-campus University of California system, has expressed strong support of the proposed requirement of conversion to the NRC. The students of the University of California were appalled at the undemocratic public hearing held by these two Congressional subcommittees. For the oral testimony only those organizations and individuals, who were opposed to the rule, were allowed to testify. Even upon request, supporters of the rule were denied permission to speak.

The chairpeople of the two subcommittees may submit a recommendation to the NRC on the proposed conversion rule based on their hearing. It is our belief that these subcommittee chairpeople are not prepared to make a sufficiently informed recommendation to the NRC based on the one sided presentations.

I have enclosed a copy of the written testimony which the Student Body President's Council submitted to the two subcommittees. As student leaders, we do not believe weapons-grade uranium belongs on university campuses, where it can not be adequately protected from theft. Considering the budgetary constraints facing universities today, we do not believe educational money should be used to provide the expensive security or to fight expensive and lengthy litigation over continued presence of HEU, which will certainly follow if the NRC does not require the removal of this bomb-grade uranium from research reactors.

The idea of exemption for any of the HEU research reactors seems to contradict the purpose of the rule which is to decrease the unnecessarily large quantity of sensitive nuclear material,

Acknowledged by card. 11/1/84 pa

which exist in the United States. The failure to require conversion of domestic research reactors and Department of Energy reactors would result in the refusal of foreign reactor operators to convert from weapons-grade uranium. The NRC has a possibility to make a decisive commitment to the reduction of nuclear proliferation. Any exemptions regardless of reasons such as uniqueness of purpose or the lifetime of the reactor's core will not be well received on university campuses throughout the country.

As the NRC may be aware, the students of American universities believe very strongly in the necessity to reduce nuclear proliferation. The Student Body President's Council has been in communication with student governments across the nation, who would be affected by a rule requiring conversion. If the NRC does not support a comprehensive, national regulation requiring conversion, we will encourage other student governments to work with their university's board of trustees and their state legislatures to require the conversion of the dangerous nuclear reactors within their state.

Thank you for your careful consideration and support of this important decision.

Sincerely,
Kevin Gillis
Kevin Gillis
Chair
Social Responsibility Committee
U.C. Student Body President's
Council

enclosed: cover letter to House Committee on Science and Technology subcommittees; testimony to the subcommittees and a resolution by the University of California Student Body President's Council supportting the proposed regulation requiring conversion from HEU to LEU.

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(113)

October 29, 1984

'84 NOV -2 A10:57

Secretary of the Commission
Nuclear Regulatory Commission
Washington, DC 20555

Attention: Docketing and Service Branch

Dear Sir,

Attached you will find my testimony

REGUARDING THE NEED TO CONVERT DOMESTIC RESEARCH REACTORS
FROM HIGHLY ENRICHED TO LOW-ENRICHED FUELS

that was submitted to the House Subcommittee on Energy Development and Applications and the Subcommittee on Energy Research and Production of the Committee on Science and Technology. I would like to submit this testimony to the NRC for your consideration on the proposed NRC rule on HEU fuels.

Sincerely,

David Hafemeister

David Hafemeister
553 Serrano
San Luis Obispo, CA 93401
(805-544-5096)

Acknowledged by card 11/2/84 pd

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(116)

1384 Morningside Way
Venice, California
90291
October 29, 1984

'84 NOV -2 A11:20

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

This is in regard to HEU Conversion Rule (49 Federal Register 27769) which provides for the conversion of all nuclear reactors which use highly enriched uranium.

I strongly support the measure; and urge that it be implemented as soon as possible.

Highly enriched uranium can be used in an atomic weapon; its use in atomic reactors, therefore, poses an unnecessary threat to national and international security. We should not wait until such fuel is stolen; we must convert these reactors now. The financial cost of conversion is insignificant compared to the potential costs involved if a successful theft of fuel were to occur.

Conversion of these reactors and removal of the weapons-grade uranium can be a signal to the rest of the world that the United States takes seriously the problem of nuclear weapons proliferation; and it could help to discourage the use of HEU fuel worldwide.

In order to be effective, conversion must be non-voluntary and must be carried out immediately.

Thank you for your consideration.

Sincerely,

Kristen K Knox

Kristen K. Knox, M.P.H.

Acknowledged by card 11/2/84 pd

-50
(49 FR 27769) (121)

Educators for Social Responsibilit
University Division
Northern California Section
441 High Street
Santa Cruz, CA 95060

October 29, 1984

Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
attention: Docketing & Service Section

RE: HEU Conversion Rule

Dear Secretary:

On behalf of Educators for Social Responsibility, University Division, Northern California Section, I write in support of a strong, mandatory, expedited rule to convert research reactors from weapons-grade uranium.

Nuclear proliferation is one of the gravest problems facing this world. Rarely are there technical solutions to these intractible problems. Conversion of reactors to low enriched uranium is one of those few technical solutions.

We are educators concerned about nuclear proliferation. We do not like the idea that bomb-grade uranium is present in kilogram quantities at a number of universities around this country.

We know university environments well. To provide the level of security necessary to adequately protect bomb-grade materials would unacceptably alter the historically open environment of university campuses, as well as being ruinously expensive in an era in which many educational institutions are hurting for funds. If there is no conversion, strict security improvements would be necessary (not merely a few paper changes); we think many universities would choose to shut their reactors down rather than face the cost and intrusion of strict security of the sort weapons-grade material should entail.

Therefore the conversion proposal is, from the point of view of educators concerned with proliferation, very sensible. We understand the government is likely to pay for the conversion and that reactor performance is essentially unaltered. For those couple of reactors for which there might be a real problem with unique research an exemption (which must be narrow and not abused) would be provided. It is essential, however, that the vast majority of these reactors convert, and convert quickly.

The consequences of theft of weapons-grade uranium from an open university campus could be devastating. The panic that could result from terrorist threat, let alone the possible explosion of a device so obtained, would produce unacceptable consequences.

Acknowledged by card 11/6/84

Universities have already become focuses of controversy and protest because of presence of weapons-grade uranium at campus reactors. The best way to prevent further controversy over these reactors is to remove the HEU and replace it with LEU. The alternative is to run an unacceptable risk of terrorist theft of nuclear bomb materials--there is no logical reason to not remove weapons-grade materials from campuses when the replacement fuels become available--and to do so for essentially all reactors, with no or extremely strict exemptions, and an expedited schedule.

Sincerely,
Sigrid McLaughlin
Sigrid McLaughlin, Ph.D.

DOCKET NUMBER PROPOSED RULE PR-50
(49 FR 27769) (114)

3271 Sawtelle Blvd.
Los Angeles, CA 90066
Oct. 30, 1984

'84 [illegible] -2 [illegible]

Docketing + Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
1717 H St. N.W.
Washington, D.C. 20555

Gentlemen:

I have just read that you have proposed to convert 31 nuclear reactors around the country to low-enriched fuel, which cannot be used in an atomic weapon.

Bravo! This is to whole-heartedly support your proposal.

The scientists have created a monster – it is surely time now, immediately, to try to curtail and control that monster. Your proposal, if put into effect, would at least be one step towards a sane and reasonable policy.

Sincerely Yours
(Mrs.) Frances Smith

Acknowledged by card 11/2/84 pd

134

PR-50
(49FR27769)

(123)

NILS J. DIAZ, DIRECTOR
W. G. VERNETSON, REACTOR MANAGER
NUCLEAR REACTOR BUILDING
GAINESVILLE, FLORIDA 32611
PHONE (904) 392-1429 TELEX 56330

NUCLEAR FACILITIES DIVISION
UNIVERSITY OF FLORIDA

'84 -5 P2:00

October 31, 1984

Secretary of the Commission
Attn: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49FR27769)

Gentlemen:

As an operator of one of 31 non-power reactors which may be affected by the subject proposed rule, we fully support the goals of no undue risk of diversion of enriched uranium from this or other licensed facilities. However, we do not believe that the achievement of acceptable risk requires the abandonment of HEU, which will be the result if the proposed rule is adopted. Therefore, we oppose the adoption of the proposed rule for reasons summarized below and presented in more detail in a similar letter from A. Francis DiMeglio on behalf of the TRTR organization.

First, it is clear that the risk of diversion of HEU from the affected facilities has not been adequately assessed as discussed in the DiMeglio letter.

Second, the use of "generic licensing" as part of the proposed rule does not adequately assure that hearings will not be required for a conversion particularly if the University of Florida utilizes SPERT-type LEU fuel which has been the subject of considerable analytical effort on our part to date. The fuel description is part of our Technical Specificatons so we are naturally concerned about the possibility of hearings and public intervention should we attempt a change in fuel type, regardless of the new type involved.

Finally, as stated by the previous University of Florida President, Robert Q. Marston, in a letter to Chairman Palladino (Attachment 1), the University of Florida has no significant problems with conversion to LEU fuel provided the funds necessary are made available by the Department of Energy or some other federal agency. Indeed, since this change, if approved, will be based on a change in National Policy and not on an identified threat, the entire cost of conversion should be at federal expense. In addition to the direct cost for new fuel, reprocessing of old fuel and facility modifications, these federal funds should be available for relicensing, including litigation and for lost overhead funds for the facility staff involved in the relicensing procedure.

Acknowledged by card 11/6/84 pd

Since we believe the licensing process cannot be assured to be hearing- and litigation-free and there is no way to assure absolutely that all costs of conversion will be borne by the responsible federal agencies, we urge you not to adopt the proposed rulemaking.

As a footnote to our concern, the money needed for the proposed rulemaking would certainly be better spent on supporting research and other educational endeavors at the University of Florida and other schools rather than address the issue of HEU at facilities such as ours where it is not a problem. We would encourage the Commission to investigate this approach on a relative merit basis.

Thank you for your consideration of these comments.

Sincerely,

William G. Vernetson

William G. Vernetson
Acting Director of
Nuclear Facilities

WGV/ps

Attachment

cc: G. Hemp, Associate Vice President
W.H. Chen, Dean, College of Engineering
M.J. Ohanian, Associate Dean, College of Engineering
J.A. Wethington, Jr., Chairman, NES Department

UNIVERSITY OF FLORIDA

ROBERT Q. MARSTON
PRESIDENT

December 19, 1983

Dr. Nunzio J. Palladino
Chairman, U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Palladino:

Thank you for your recent letter regarding the use of highly-enriched uranium (HEU) fuel at university research reactors. We are certainly sensitive to this situation, especially as it relates to the worldwide efforts to minimize the use of HEU in research, test and training reactors. Our position on this matter is as stated in the attached letter from the manager of our reactor, Dr. Vernetson to Dr. Harris, Chairman of the Nuclear Regulatory Commission sponsored Low Enriched Uranium (LEU) Study Group.

Basically, we have no significant problems with conversion to LEU fuel provided the funds necessary for such conversion are made available by the Department of Energy or another cognizant federal agency.

Cordially yours,

Robert Q. Marston
President

Attachment

cc: N.J. Diaz
M.J. Ohanian
W.G. Vernetson✓
J.A. Wethington, Jr.

PR-50
(49 FR 27769) (1.10)

Department of Energy
Washington, D.C. 20585

OCT 31 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Docketing and Services Branch

Gentlemen:

The Department of Energy appreciates the opportunity to comment on the Nuclear Regulatory Commission's proposed rule relating to the use of reduced enrichment fuels in domestic research and training reactors. The Department strongly supports U.S. initiatives to prevent nuclear weapons proliferation. We question, however, some aspects of the rule that we believe are not cost beneficial. Specifically, we do not believe that low power U.S. research and training reactors with lifetime cores or fuel supply should be required to convert. We also do not believe that conversion should be required for U.S. reactors where the change would entail significant economic or performance penalties.

Last year, in testimony before the Commission, the Department supported the conversion from High Enriched Uranium (HEU) to Low Enriched Uranium (LEU) for U.S. university reactors refueled on an annual basis, provided that acceptable LEU fuel was available. We believe that this step is logical if we are to encourage foreign research reactor operators to convert from HEU to LEU fuel. We also volunteered to store fresh HEU at secure Department of Energy sites to reduce the on-campus inventory. The Department is also involved in several other activities in support of the technical aspects of the reduced enrichment program.

Our support of these conversion activities assumes that the LEU fuel will be phased in as the existing HEU fuels are used up. We do not believe that conversion of U.S. research reactors should be required if a significant economic or technical penalty would result. We are also concerned about the universities' ability to survive the relicensing requirements that may be necessary, and urge the Commission to do all possible to lessen the impact of the conversion process. These university facilities are essential for the education and training of future nuclear scientists and engineers. They are also widely used for health, medical, and agricultural research applications. It would be intolerable if such valuable resources were to be put in jeopardy.

Our disagreement with the proposed rule centers on its treatment of U.S. reactors that have essentially a lifetime supply of fuel. With the exception of four one-megawatt TRIGA reactors, these are small, low-powered reactors with in-core inventories of less than five kilograms of U-235. Our opposition is based on the following considerations:

Acknowledged by card. 11/1/84 pd

1. We understand that the U.S. Government is not seeking conversion of foreign reactors with lifetime cores.

2. We believe that the theft or diversion of fuel from these lifetime radioactive cores is unattractive, and, therefore, extremely improbable. The total of unirradiated fuel at all 14 of these small reactors (250KW and below) is less than 4KG's. The four-one megawatt TRIGA reactors use a seventy percent U-235 enriched fuel. This fuel contains a uranium-erbium-zirconium hydride mixture from which extraction of the uranium, in a pure form, is extremely difficult. The difficulties of removing the intensely radioactive elements from the reactor, plus the technical and financial resources needed to separate the uranium in sufficient amount for a nuclear explosive, make the threat, if any, extremely remote.

3. If conversion of these reactors is mandated, some are almost certain to cease operation. For negligible benefit, we will have lost a valuable training and research capability.

In conclusion, if the NRC believes that a rule on conversion is warranted, it should exempt from that rule all university reactors with a lifetime fuel supply. The conversion of other U.S. HEU-fueled reactors should be required only after existing stocks of HEU elements are used up, and only if conversion can be done without a large technical and economic penalty. The latter is the criterion used in considering the conversion of foreign reactors.

The Department of Energy will be pleased to work with the Commission in achieving these goals.

Sincerely,

Alvin W. Trivelpiece
Director, Office of
Energy Research

Vol. 2

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

DOCKET NUMBER
PROPOSED RULE PR-50 (118)
(49 FR 27769)

October 31, 1984

DOCKETED
NOV 2 1984
DOCKETING & SERVICE BRANCH
SECY-NRC

Docketing & Service Branch
Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

Please consider my enclosed Supplementary Comments, as well as the enclosed Statement submitted to the Lloyd and Fuqua Subcommittees in your review of public comments on the proposed HEU conversion rule. Thank you.

Sincerely,

Steven Aftergood

Steven Aftergood
Executive Director

Acknowledged by card 11/2/84 pd

PR-50 (118)
(49 FR 27769)

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE #203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

October 31, 1984

'84 NOV -2 P2:19

Supplementary Comments on the HEU Conversion Proposal

The Committee to Bridge the Gap favors the NRC proposed rule requiring conversion of domestic research reactors, as previously indicated. Following are supplementary comments on specific issues or aspects of the proposal.

Virtually Any HEU-Fueled Reactor Potentially Contains Enough HEU for a Weapon

It has been suggested that the quantity of HEU needed for a single explosive is more than the inventory of any one low power reactor, and that therefore these can be exempted from the rule. This is in error for at least a couple of reasons.

The Commission has already heard testimony that the fast critical mass of an implosion-type weapon can be quite low, even lower than the NRC's somewhat arbitrarily designated "formula quantity". Most of the details of construction of such a weapon are all too readily accessible. Therefore, any single reactor facility with kilogram quantities of HEU on site must be considered a potential target for theft or diversion, and cannot be exempted from the proposed rule.

More broadly, the potential for extortion or other threats of even a tiny quantity of HEU is enormous, aside from its potential for actual utilization in a weapon. A first successful theft of HEU (or even a convincing attempt) would be a disaster on many levels and,

11/2/84

incidentally, would mean the prompt demise of many research reactor programs.

One commenter has asserted that there is not enough HEU reactor fuel in existence to make a single fast fission device. This astonishingly naive proposition is based on the absurd assumption that what is under consideration is a weapon constructed from unprocessed fuel plates! The commenter goes on to state that removal of HEU from the fuel plates is "not impossible," but decidedly "difficult." This is a dangerous misunderstanding. Extraction of HEU from fuel plates, even lightly irradiated ones is, relatively speaking, quite simple.

(Note that this is particularly true of the low power reactors, which have a low burnup rate, and are not highly radioactive. From this and other points of view, these reactors appear to be among the most attractive potential targets. It is appropriate that they should be among the first to convert.)

ALTERNATIVES: Conversion Fuel is Available Now

One alternative to conversion of plate type reactors to the new high density LEU fuels is conversion to TRIGA-type LEU fuel. Though many such conversions have already taken place, this alternative appears to have received little consideration.

GA Technologies of San Diego currently has commercially available 19.7% enriched TRIGA-type fuel. The GA publication "TRIGA" (Attachment A) at page 11 shows a photograph of the replacement TRIGA bundle alongside a standard flat-plate bundle. As indicated in the section on "Research Reactor Conversions":

> A number of reactors originally built for plate type fuel elements have been converted to use TRIGA fuel. In most instances, the converted reactors have retained their existing core grid structure, control rod drives, and control console.

Attachments B (page 5) and C list numerous research reactors originally utilizing plate type fuel which have been successfully converted to TRIGA fuel. These include Penn State, Washington State, the University of Wisconsin, Texas A & M, the University of Maryland, and a number of others.

A Dr. Muno of the University of Maryland reactor staff confirmed to us that conversion of the Maryland reactor took place in 1974. LEU was chosen because it was anticipated that the NRC would eventually require a high degree of security for HEU, and that it would be unlikely that the reactor staff could convince the University to provide armed guards, and the like. TRIGA fuel was chosen for its inherent safety features, primarily the prompt negative temperature coefficient which provides a far greater degree of protection against destructive power excursions than found with flat-plate fuel.

Dr. Muno indicated that a slight drop in flux upon conversion to TRIGA LEU fuel could be compensated for by a more efficient geometry, and that in any case, the current flux was more than adequate for the University's needs (mainly activation analysis). One researcher in materials science occasionally required a high flux of around 10^{14} nvt, so he would send his samples off to Argonne or Oak Ridge.

We confirmed with the TRIGA division of GA Technologies the current commercial availability of TRIGA LEU fuel for plate-type reactors and that conversion to TRIGA LEU fuel involves no significant drop in neutron flux. We were informed that the average flux is comparable, though the shape will vary. Water-filled flux traps can increase the available flux; even without such flux traps, though, the reactor would still be able to perform the same functions as prior to conversion. Furthermore, conversion rarely requires changes to the control rod or cooling system.

GA, we were assured, currently has commercially available LEU TRIGA fuel for conversion of plate-type reactors and is "ready, willing, and able" to perform conversions as they come up. The safety features of TRIGA LEU and its current availability, as well as GA's experience in carrying out conversions, may make it an attractive alternative for some facilities which now use flat-plate type HEU.

We conclude that the Federal Register Notice (49 FR at 27771) is at least partially in error in stating that

> successful implementation of the proposed rule ... depends on (1) the continued success of the DOE funded RERTR program (2) the development of acceptable, and available, replacement fuel, and...

Acceptable replacement fuel is now available, independently of the RERTR program, in the form of TRIGA LEU fuel.

Will Conversion Lead to Shutdown of Reactor Facilities?

This concern is backwards. We have argued in detail elsewhere that it is non-conversion which will lead to greater pressure on licensees and hence a greater possibility of shutdown. (see enclosed

Statement to Lloyd-Fuqua Subcommittees, pp. 6-9).

The alternative to conversion is not really an alternative at all for most facilities, especially academic institutions, namely a drastic increase in security. The current and even the new proposed NRC security upgrade requirements, when compared to those in place at government and military installations using HEU, appear largely cosmetic. Ultimately, we believe, and perhaps very soon, required security precautions for HEU use will include 24 hour armed guard presence, perimeter defenses, metal detectors, and other high-security measures. If world conditions continue to deteriorate, and the threat of terrorism spreads, campus facilities will be more, not less vulnerable. Security requirements will be upgraded, at licensee expense, not reduced.

The only public concerns expressed to date about reactor fuel have been about the use of weapons-grade fuel, not about LEU. Given the international security implications of HEU use and the easy availability of an alternative, these pressures will only intensify. It is best to deal with them now, in an orderly fashion. The NRC proposal is a responsible attempt to do just this.

Generic Licensing

Though we have previously expressed opposition to generic licensing, we would not oppose it, in order to expedite implementation of conversion, if the following conditions were observed:

There should be opportunity for public comment and review of the proposed envelopes of safety limits.

The generic licensing procedure must not be used to allow changes in reactor operation unrelated to conversion such as increases in power level or excess reactivity, for example, or pulsing mode operation. Any such unrelated changes would have to be pursued through the normal amendment procedure.

The Case of UCLA

The UCLA reactor relicensing proceeding, which concluded with shutdown of the reactor, has been cited time and again as "a casualty of litigation" or something similar. This claim is not based on facts.

In the first place, the Chancellor of the University, in withdrawing the application for relicensing, claimed the decision was based on academic factors, including the decline in student enrollment and curtailed research applications, and this is certainly part of the explanation. Indeed, in one recent year, the Atomic Safety and Licensing Board found that the reactor had been used a mere 31 hours for educational purposes, and hundreds of hours for commercial functions, in violation of its license.

But a review of the record of the UCLA proceeding reveals profound safety problems at the facility which the University was unwilling to address. To give just a handful of examples, which serve to portray not only an extraordinarily dangerous facility, but also a grievous lack of regulation on the part of the NRC:

--The reactor, designed for $1 of excess reactivity, was licensed for $3.50(!), about the same amount which produced a destructive power excursion in SPERT and BORAX cores.

--UCLA's own Hazards Analysis predicted radiological health consequences to the public in the event of a major accident far in excess of regulatory limits. The reactor had no containment and no low-population buffer zone.

--The exhaust stack, which released radioactive Argon-41 gas whenever the reactor operated, was lower than adjacent buildings, and directly upwind of an air conditioning inlet, so that the stack was feeding the air supply of neighboring classrooms.

--Due to miscalibration of monitors, Argon-41 release to the environment was underestimated by a factor of 300.

--Security: Hinges on doors to supposedly secure areas were located on the outside of the door, where they could be easily removed; the alarm system was on occasion found to have been "tuned down" so far that it could not be even intentionally activated; HEU was stored in an ordinary filing cabinet; key control was extremely poor; police response was uncertain; etc.

NRC regulations provide for a summary disposition procedure, by which allegations which have no factual basis can be dismissed without hearing. For obvious reasons, all of the safety and security problems at UCLA were found to require hearing.

It is no wonder that not a single member of UCLA's distinguished nuclear engineering faculty would testify in defense of the reactor. On the other hand, over a dozen experts of national repute, in disciplines ranging from reactor physics to metallurgy of reactor fuel, and including health physics and physical security, volunteered their time to bring to the Licensing Board's attention major flaws in the design and operation of the reactor.

The Licensing Board judges regularly chided the University for its superficial (their word), evasive, inadequate defense. In point of fact, the reactor, in its then-current configuration, was not defensible.

Why did the proceeding last so long? A primary reason was UCLA's interest in delay. As long as no conclusion was reached, the reactor was permitted by law to continue to operate. Another reason was the repeated misrepresentations on the part of University and Staff representatives, which required many months to address. But as much as anything else, the explanation appears to be political. An NRC employee in a position to know told us that the Licensing Board was reluctant to issue the inevitable ruling that the reactor was unsafe. To avoid this unprecedented conclusion, the judges gave UCLA repeated opportunities for rebuttal and for supplementary testimony.

All to no avail. UCLA was not a victim of litigation, but of an unsafe reactor whose safety deficiencies it was unwilling to correct. It should be pointed out that as Intervenors, it was never our purpose to shut down the facility. From the beginning, we supplied UCLA with a list of specific safety concerns which could have been resolved with a fraction of the funds spent on litigation (e.g. reduction in excess reactivity, elevation of the exhaust stack, conversion to LEU). UCLA chose the hard way.

In the current context, the most important lesson for other licensees is in the controversy over UCLA's use of HEU. Had the reactor been fueled with LEU, the major security problems at the site, and a substantial portion of the safety problems would have been resolved. With LEU, the UCLA reactor might still be operating.

It is worth noting in this connection that it would have been easier and cheaper to convert UCLA to LEU than almost any other reactor. This is because the University of Florida's Argonaut reactor appears to have on site enough 4.8% enriched SPERT LEU fuel to convert all five Argonauts in the country, including UCLA's. (see Attachment D). This fuel would be available essentially for free. Furthermore, the University of Florida has already performed extensive safety analyses of conversion of their reactor, most or all of which would have been directly applicable to UCLA's, further reducing the burden on the latter.

Will the Committee to Bridge the Gap Intervene to Block Conversion License Amendments?

The Committee to Bridge the Gap will not, under any circumstances, intervene to block conversion to LEU. Nor will we assist any other group or individual to do so.

However, if the proposed rule were overturned or weakened, e.g. to exclude reactors with lifetime HEU cores, we would diligently assist in legal and other efforts to promote conversions at affected reactors. (See letter from S. Aftergood to E. Ricci, Attachment E).

Relative Value of Reduced Risk of Diversion or Theft of HEU

The low power research reactors which use HEU, including those with lifetime cores, present the greatest risk of theft or diversion of any category of research reactor, or most other nuclear facilities, for that matter. This is true for several reasons.

Because they are operated at low power, and even so only irregularly, they are not highly radioactive at all. Compared to high power reactors, the radiation level of the low-power fuel is so low that it presents virtually no deterrent at all to a potential thief. Most of these reactors are incapable of sustaining even the minimal 100 rem/hr/bundle at 3 feet, which has been called a "self-protecting" level, though this is highly arguable.

Secondly, and for the same reason, this fuel is relatively easy to reprocess. At most, some stages of separation would need to be performed by remote control. This makes it especially attractive.

Most important of all, the security precautions at most university facilities are scandalously poor. Certainly, in a relative sense, these facilities are by far the most vulnerable of any reactors. They do not begin to match the sophisticated security apparatus found, for example, at DOE facilities. Security at fuel fabrication facilities and weapons facilities are, in turn, even greater.

In an absolute sense, security at campus reactors is minimal at best. First of all, if Staff counsel in the UCLA proceeding is to be believed, there is no NRC requirement to protect against theft, only to detect and report it.

NRC Staff is currently considering whether or not to impede unauthorized removal of HEU, and whether or not to arrange for a single, armed law enforcement agency respondant! The problem is not that such considerations are belated, they are totally unacceptable.

They do not begin to seriously address the risk of theft or diversion.

It is therefore most logical, and indeed vital, that conversion should begin with the facilities at greatest risk-- the campus reactors.

Conversion Schedule

In view of the national and international security interests involved, conversion should be carried out as soon as possible once suitable replacement fuel is available, which in almost all cases it appears to be already.

The 12 month period cited in the implementation provisions of the rule for development and submission of a proposed schedule appears excessive. We propose that this period be reduced to six months, with a target date for completion of conversions to be 24 months or less from the effective date of the rule.

Given this framework of a two year implementation period, the licensee should be permitted to take into account "reactor usage" factors, and to schedule conversion at a time which is most advantageous to the facility.

Availability of shipping casks would not appear to be a serious constraint, since a cask would be required only for a matter of days. If, nevertheless, there appears to be a shortage of casks, this will be evident well in advance (or may be already), and additional casks should be purchased or otherwise acquired as soon as possible.

The "Unique Purpose" Exemption

The unique purpose provisions appear to have been designed to eliminate injury to national research interests by exempting from conversion those few facilities whose programs could not carry on without use of HEU.

We believe the criteria for an exemption should be narrowed as follows:

In itself, "a specific experiment" requiring HEU use is insufficient grounds for an exemption. Isolated experiments could conceivably be carried out at another facility, such as a national lab, contracted out for this specific purpose.

In all cases, there should be provisions for assessing the merit of the request for exemption. In other words, the licensee should have to demonstrate not only the need for HEU for certain research, but also the value of the proposed research. And this value should be such as to outweigh the national interest in reducing the use of HEU.

Such a determination necessarily includes some subjective elements, and it should not be left alone to the Director of Nuclear Reactor Regulation. Approval of any exemption from conversion should require approval of a majority of the Commissioners.

Further, while conversion may be expedited through generic licensing or minor license amendments, those facilities requesting an exemption from conversion should be closely scrutinized. Requests for exemption which are to be considered by the Commission should be published, and the opportunity for public review and comment allowed.

Any exemptions granted should not be open-ended, but should be periodically reviewed to determine if suitable replacement fuel has become available, and if the unique purpose is still being fulfilled.

The Pollack Memorandum

In 1983, Dr. Gerald L. Pollack of Michigan State University performed an exhaustive survey of the 23 academic institutions which use HEU to determine their positions on conversion and to assess any problems which might arise.

Pollack concluded that "the reactor administrators are generally in favor of the conversions to LEU and would be cooperative." Because of its comprehensive nature, and the contrast it provides with statements of some commenters, Pollack's Memorandum is submitted for review herewith as Attachment F.

Concluding Remarks

The Commission has for several years affirmed the policy goal of minimizing as far as possible the use of HEU, in domestic and foreign research reactors. The current proposed rule represents the first step towards achieving this goal. If the Commission is serious about non-proliferation, it is essential that its long-standing commitment begin to be finally actualized, and not reversed or watered-down at the first opportunity.

The NRC proposal is not a total solution to the problem of nuclear proliferation; it is not intended to be. But it is vital in and of itself, and it is an essential first step towards a more complete reduction in HEU use, at home and abroad.

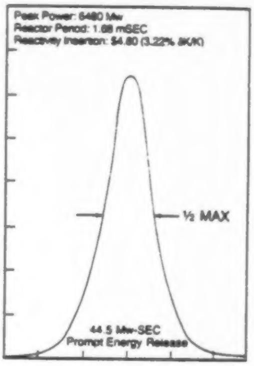
Attachment A

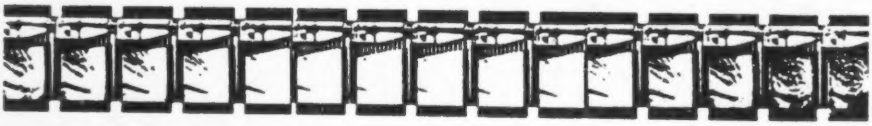
Pulsing to 22,000,000 kw

Pulsing Extends Applications. The TRIGA reactor's controlled pulsing operation, made possible by its built-in safety, has opened up important new reactor applications. This pulsing capability may be used to investigate reactor kinetics and transient testing of power reactor fuel, or to study the effects of extreme radiation environments on biological and electronic systems. Pulsing may also be used for the production of very short half-life isotopes, and in many other basic studies where high-intensity pulses of neutron and gamma radiation are required.

The 1500 kw TRIGA reactor at General Atomic has been used extensively to prove the pulsing capability of TRIGA fuel. This reactor has been pulsed safely to peak power levels well in excess of 8,000,000 kw. More than 50,000 pulses on all TRIGA reactors have demonstrated the performance, safety and high reliability of TRIGA fuel.

Annular core pulsed reactors have been designed for routine pulsing to power levels of 22,000,000 kw.





TRIGA Safety

Inherent Safety. The TRIGA reactor's inherent safety is due primarily to a physical property of its uranium-zirconium hydride fuel elements, which gives the TRIGA core a large *prompt* negative temperature coefficient. Power rises initiated by the rapid insertion of large amounts of excess reactivity are automatically suppressed without external controls and the reactor immediately returns to normal operating levels. By contrast, a *delayed* negative temperature coefficient found on conventional reactors provides safety only against relatively small insertions of excess reactivity.

A combined total of more than 500 reactor years of safe operation has been achieved by TRIGA reactors throughout the world. The proven and inherent safety of TRIGA reactors permits installation in a conventional building and siting in urban areas such as university campuses, hospitals or classrooms. Installation within a conventional building without the need for a pressure type containment results in significant savings in facility construction costs and the potential for economical installation in an existing building.

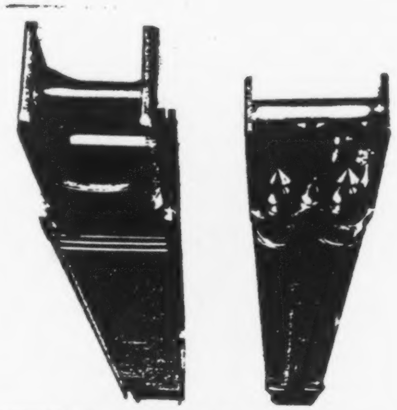
Research Reactor Conversions

A number of reactors originally built for plate-type fuel elements have been converted to use TRIGA fuel. In most instances, the converted reactors have retained their existing core grid structure, control rod drives, and control console. In addition to increased safety and flexibility, the TRIGA conversion has provided a dual steady state/pulsing capability with steady state performance levels up to 2 MW, still with natural convection cooling of the core. The conversion to a complete TRIGA core can be a step-wise process whereby TRIGA 4-rod clusters are added a few at a time to an operating plate-type core.

General Data

22 fuel clusters for 1 MW operation; 4 fuel rods to each cluster, containing UZrH using uranium enriched to 20%.

Up to 2000 kw steady state power level; 2,000,000 to 6,400,000 kw pulse power levels.



High Power Level Reactor Conversions

The 16-rod, 25-rod and 36-rod fuel clusters used in TRIGA reactors for steady state operation at 5 MW to 25 MW are designed to be installed in reactors originally incorporating plate-type elements. Conversion of a plate-type reactor to a high power TRIGA reactor permits use of the existing forced circulation cooling system but gains the inherent safety characteristics of TRIGA reactors and the improved fuel cycle economics.

General Data

Square fuel cluster containing 4x4, 5x5, or 6x6 rods, dependent upon final power level.

[illegible] rod contains 20% enriched UZrH fuel with erbium burnable poison.

Inspection of finished TRIGA fuel elements.

1850

Attachment B

CON-11 (Rev. 1)

ADVANTAGES OF TRIGA FUEL FOR RESEARCH REACTORS

October 1981

CON-11 (Rev. 1)

ADVANTAGES OF TRIGA FUEL FOR RESEARCH REACTORS

All TRIGA fuel is made by GA with a uranium enrichment of just under 20% and thus is classified as Low Enrichment Uranium (LEU) fuel.

The following discussion of advantages applies to TRIGA fuel clusters which can be inserted in existing grid plates to convert plate-type fueled reactors, and some pin-type fueled reactors, to TRIGA. TRIGA's advantages have motivated the owners of twelve plate-type fueled reactors to convert to the use of TRIGA fuel. TRIGA LEU fuel is available now for use in existing reactors operating at steady state power levels to 50 MW.

1. UNIQUE SAFETY

All of GA's research and test reactors are fueled with UZrH. This unique fuel provides the highest degree of safety available in any type of nuclear reactor. In these days of increasing public concern with perceived hazards of nuclear facilities, these safety advantages alone should justify use of UZrH fuel.

A. The UZrH fuel has a prompt negative temperature coefficient of reactivity, vs. a delayed coefficient in aluminum-clad plate-type fuel. This allows UZrH cores to safely withstand accidental reactivity insertions that have completely destroyed plate-fueled cores.

B. UZrH is chemically stable. It can be safely quenched at 1200°C in water, while exothermic metal-water reactions take place with aluminum at 650°C.

C. High-temperature strength and ductility of TRIGA's Incoloy-800 fuel cladding provide a yield strength greater than 10,000 psi at 900°C. The aluminum cladding on plate-type fuels melts at about 650°C.

D. The UZrH fuel material has very superior fission product retention. The aluminum-clad plate-type fuels melt at 650°C, releasing 100% of the volatile fission products. Whereas, at this same temperature UZrH retains about 99.9% of these fission products even with the cladding removed.

E. New TRIGAs do not require expensive pressure-containment buildings because of these unique safety features.

2. ECONOMY

A. Major operating cost savings result from the fact that UZrH fuel contains several times as much U-235 as plate fuels. GA sells its fuel at standard published fixed prices with standard terms and a commercial warranty. Although the initial cost of UZrH fuel is usually higher than plate fuel, the total fuel cycle costs are lower for UZrH due to the much longer core life, and reduced shipping and reprocessing costs.

B. Individual fuel rods within a cluster can be easily replaced in case of damage (vs. replacement of entire plate-type element).

C. There are fewer reactor shutdowns (with corresponding savings in fuel handling costs and increased experiment time/continuity) because fewer core changes are required with TRIGA fuel.

D. Uranium costs are lower because TRIGA's uranium lasts as long as that in several plate-type cores, which must be purchased at prices that are continuing to escalate.

E. Less time and money is spent on inter-government problems to export/import fuel and the contained uranium since TRIGA fuel outlasts several plate-type cores. Thus the potential for unplanned reactor shutdowns due to slow or delayed fuel delivery is significantly reduced.

3. PULSING OPERATION

A. Routine pulsing is not possible with plate-type fuel but is a normal mode of operation with most TRIGAs. Since 1958, TRIGA reactors have pulsed over 50,000 times.

B. Standard TRIGA fuel with 8.5 wt-% uranium is licensed for routine pulsing with reactivity insertions of 3.2% δk/k up to a peak power of about 6,400,000 kW. The prototype TRIGA at GA has been pulsed with reactivity insertions of 3.5% δk/k to a peak power of about 8,400,000 kW. Pulsing allows production of very short-lived isotopes, transient testing of materials, and other unique applications.

C. The TRIGA-ACPRs (Annular Core Pulse Reactors) at the Japan Atomic Energy Research Institute and the Institute for Nuclear Technologies in Romania are in operation and pulsing to ~20,000,000 kW for safety testing of power reactor fuels.

4. LARGER EXPERIMENT REACTIVITIES AND MORE FLEXIBLE OPERATIONS

A. Due to its larger prompt negative temperature coefficient, TRIGA can safely withstand larger accidental reactivity insertions which mean maximum flexibility for student use, training and experiments.

B. TRIGAs are licensed for in-core experiments having a reactivity worth of up to 2.1% δk/k for one experiment and a total of 2.8% δk/k for several.

C. TRIGA is also less sensitive than plate-fueled reactors to reactivity changes in the reflector region. As a result, the TRIGA core can be moved from a position with a void on one side to a position which is completely reflected by water without removing fuel elements.

D. TRIGA's special square wave mode of very fast reactor startup (rise to normal steady state power levels in a few seconds) is available on all TRIGA pulsing reactors. This mode of operation, which is possible due to TRIGA's large prompt negative temperature coefficient, means higher utilization, more "on-line" time and reproducibility of irradiation doses.

5. LICENSE PRECEDENTS

Because of their inherent safety, TRIGA reactors are currently licensed for the following types of experiments:

A. In-core pneumatic transfer systems under both steady-state and pulsing modes of operation;

B. In-core experiments at cryogenic temperatures;

C. In-core experiments at temperatures of up to 2000°C;

D. In-core experiments at elevated temperatures in which samples of fissile material can be subjected to both steady-state and pulsing conditions;

E. In-core experiments in which explosives are detonated.

6. PROVEN RELIABILITY

A. Sixty-three TRIGA reactors have been or are being constructed throughout the world, and of these, 34 routinely operate in the pulsing mode.

B. TRIGA reactors have greater than 800 reactor years of safe operating experience and over 50,000 pulses.

7. FUEL GUARANTEE AND SUPPLY

A. TRIGA LEU fuel is the only LEU fuel currently available in power levels to 50 MW steady state.

B. GA designs, develops, manufactures, and guarantees the TRIGA fuel.

C. GA stocks spare fuel for the immediate, unplanned needs of customers; TRIGA fuel may be purchased a few elements at a time as the need arises.

D. The continuing requirements of the many TRIGA reactors in operation give assurance of a continuing, reliable fuel and spare parts supply.

8. PREFERENCE OF TRIGA BY EXPERIENCED CUSTOMERS

A. More TRIGA reactors are in operation than those of any other research reactor manufacturer.

B. TRIGA is still the most widely chosen research reactor; no type of research reactor other than TRIGA has been purchased commercially anywhere in the world since 1968.

C. The TRIGA system was chosen by the following experienced reactor groups for conversion of their plate-type research reactors to TRIGA fuel:

1) Pennsylvania State University
2) Washington State University
3) University of Wisconsin
4) Texas A&M University
5) USAEC at the Puerto Rico Nuclear Center
6) University of Maryland
7) Aerojet Corp., California
8) University of Frankfurt, Germany (water-boiled type)
9) Office of Atomic Energy for Peace, Thailand
10) Nuclear Research Center, Iran
11) National Tsing Hua University, Taiwan
12) Atomic Energy Commission, Philippines

9. GENERAL ATOMIC CAPABILITIES/SERVICES

A. Corporate assets of GA's owners is over $50 billion.

B. GA is the world's largest and only remaining U.S. research reactor supplier.

C. GA designs and manufactures control rod drives and complete nuclear instrumentation and control systems for reactor facilities which also wish to update these components. GA's instrumentation and control systems use state-of-the-art, micro-processor-based electronics making extensive use of integrated circuits; these systems are used in power reactors and therefore are designed to meet stringent safety requirements.

D. GA's competent staff of nuclear physicists, engineers, seismic experts and reactor designers has the most modern techniques and computational equipment to perform any safety or reactor analyses that may be required as part of a reactor conversion or its licensing. The current TRIGA staff, with 200 man-years of TRIGA reactor engineering experience, is also available for consultation on any aspect of nuclear facility planning, engineering or operation.

E. GA routinely conducts in-depth training and technology transfer programs for TRIGA customers. The two TRIGA reactors owned and operated by GA at its San Diego laboratories are utilized to provide "hands on" operational experience to supplement the lectures and homework assignments. At the conclusion of the course, U.S. students take the U.S. Nuclear Regulatory Commission Senior Reactor Operators license examination; foreign students take a similar exam administered by the GA staff.

F. TRIGA owners in the U.S. and in Europe hold bi-annual TRIGA Owners Conferences where experimental work, innovative ideas, reactor modifications and common problems associated with the nuclear community are discussed and, where appropriate, united actions taken. The proceedings of these meetings are published and distributed to all TRIGA owners.

G. GA's TRIGA Reactor Division is dedicated to the continuing improvement and reliability of TRIGA reactors.

Attachment C

TRIGA® Reactors

INSTALLATIONS AND CONVERSIONS

GENERAL ATOMIC

GEN-10
Feb 1980

	LOCATION	TYPE	MAXIMUM RATING		INITIAL CRITICALITY
			STEADY STATE	PULSING	
Arizona	1 University of Arizona Tucson	TRIGA Mark I	250 kW	300,000 kW	12-7-58
California	2 General Atomic San Diego	TRIGA Mark I	250 kW	600,000 kW	5-3-58
	3 General Atomic San Diego	TRIGA Mark F	1,500 kW	6,400,000 kW	7-2-60
	4 General Atomic San Diego	TRIGA Mark III	Decommissioned		1-17-66
	5 Norair Division of Northrop Corporation Hawthorne	TRIGA Mark F	1,000 kW	1,500,000 kW	3-6-63
	6 University of California Berkeley	TRIGA Mark III	1,000 kW	2,000,000 kW	8-10-66
	7 University of California Irvine	TRIGA Mark I	250 kW	250,000 kW	11-25-69
	8 Aerotest Operations San Ramon	TRIGA Conversion	250 kW		7-6-65
Colorado	9 U.S. Geological Survey Denver	TRIGA Mark I	1,000 kW	1,200,000 kW	2-26-69
Idaho	10 Argonne Nat'l. Lab. West (HPEF, INEL) Idaho Falls	TRIGA Converted	250 kW		10-12-77
Illinois	11 University of Illinois Urbana	TRIGA Mark II	1500 kW	6,000,000 kW	8-16-60
Kansas	12 Kansas State University Manhattan	TRIGA Mark II	250 kW	250,000 kW	10-16-62
Maryland	13 Harry Diamond Laboratories (U.S. Army) Forest Glen	TRIGA Mark F	Decommissioned		9-16-61
	14 Nuclear Agency (AFRRI) Bethesda	TRIGA Mark F	1,000 kW	2,000,000 kW	6-26-62
	15 University of Maryland College Park	TRIGA Conversion	250 kW		6-13-74
Michigan	16 The Dow Chemical Company Midland	TRIGA Mark I	100 kW		7-6-67
	17 Michigan State University East Lansing	TRIGA Mark I	250 kW	250,000 kW	3-21-69
Nebraska	18 Veterans Administration Hospital Omaha	TRIGA Mark I	18 kW		6-26-59
New Mexico	19 Sandia Corporation (USAEC) Albuquerque	TRIGA-ACPR	600 kW	12,000,000 kW	6-2-67
New York	20 Columbia University New York	TRIGA Mark II	250 kW	250,000 kW	Licensed
	21 Cornell University Ithaca	TRIGA Mark II	100 kW	250,000 kW	1-12-62
Oregon	22 Oregon State University Corvallis	TRIGA Mark II	1,000 kW	3,200,000 kW	3-8-67
	23 Reed College Portland	TRIGA Mark I	250 kW		7-2-68
Pennsylvania	24 Pennsylvania State University University Park	TRIGA Mark III Conversion	1,000 kW	2,000,000 kW	12-31-65
Puerto Rico	25 Puerto Rico Nuclear Center Mayaguez	TRIGA Conversion	Decommissioned		1-19-72
Texas	26 Texas A & M University College Station	TRIGA Conversion	1,000 kW	2,000,000 kW	8-1-68
	27 University of Texas Austin	TRIGA Mark I	250 kW	250,000 kW	8-3-63
Utah	28 University of Utah Salt Lake City	TRIGA Mark I	250 kW		10-25-75
Wisconsin	29 University of Wisconsin Madison	TRIGA Conversion	1,000 kW	2,000,000 kW	11-14-67
Washington	30 Washington State University Pullman	TRIGA Conversion	1,000 kW	2,000,000 kW	7-14-67
	31 Westinghouse-Hanford - 300 Area Richland	TRIGA Mark I	250 kW		3-26-77

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TRIGA® REACTORS Research, Training, and Isotope Production

	LOCATION		TYPE	MAXIMUM RATING		INITIAL CRITICALITY
				STEADY STATE	PULSING	
Austria	32	Federal Ministry of Education Vienna	TRIGA Mark II	250 kW	250,000 kW	3-7-62
Bangladesh	33	Institute of Nuclear Technology, Dacca Bangladesh	TRIGA Mark II	3,000 kW	1,200,000 kW	Under Construction
Brazil	34	University of Minas Gerais Belo Horizonte	TRIGA Mark I	250 kW		11-6-60
England	35	Imperial Chemical Industries Billingham, Teesside	TRIGA Mark I	250 kW		8-19-71
Finland	36	The State Institute for Technical Research Helsinki	TRIGA Mark II	250 kW	250,000 kW	3-27-62
Germany	37	German Cancer Research Center Heidelberg	TRIGA Mark I	250 kW		8-25-66
	38	Johannes Gutenberg University Mainz	TRIGA Mark II	100 kW	250,000 kW	8-3-65
	39	Association for Radiation Research Munich	TRIGA Mark III	1,000 kW	2,000,000 kW	8-23-72
	40	Medical College of Hanover Hanover	TRIGA Mark I	250 kW		1-31-73
	41	University of Frankfurt Frankfurt	TRIGA Conversion	1,000 kW	1,000,000 kW	Under Construction
Indonesia	42	National Atomic Energy Agency Bandung	TRIGA Mark II	1,000 kW		10-16-64
	43	National Atomic Energy Agency Yogyakarta	TRIGA Mark II	250 kW		1979
Iran	44	Nuclear Research Center Tehran	TRIGA Conversion	5,000/10,000 kW		Under Construction
Italy	45	National Committee for Nuclear Energy Rome	TRIGA Mark II	1,000 kW		6-10-60
	46	University of Pavia Pavia	TRIGA Mark II	250 kW	250,000	11-15-65
Japan	47	Japan Atomic Energy Research Institute Tokai Mura	TRIGA-ACPR	300 kW	22,000,000	6-30-75
	48	Musashi College of Technology Tokyo	TRIGA Mark II	100 kW		1-29-63
	49	Rikkyo University Yokosuka	TRIGA Mark II	100 kW		12-8-61
Korea	50	National Atomic Energy Institute Seoul	TRIGA Mark II	250 kW		3-19-62
	51	National Atomic Energy Institute Seoul	TRIGA Mark III	2,000 kW	2,000,000 kW	4-10-72
Malaysia	52	Tun Ismail Atomic Research Centre Kuala-Lumpur	TRIGA Mark II	1,000 kW	1,200,000 kW	Under Construction
Mexico	53	National Commission for Nuclear Energy Mexico City	TRIGA Mark III	1,000 kW	2,000,000 kW	11-8-68
Morocco	54	Mohammed V University Rabat	TRIGA Mark I	100 kW		Under Construction
Romania	55	Institute for Nuclear Technologies Bucharest	TRIGA-ACPR	500 kW	15,000,000 kW	12-1-79
	56	Institute for Nuclear Technologies Bucharest	TRIGA	14,000 kW		11-18-79
Taiwan	57	National Tsing Hua University Taipei	TRIGA Conversion	1,000 kW		8-1-77
Thailand	58	Office of Atomic Energy for Peace Bangkok	TRIGA Mark III Conversion	2,000 kW	2,000,000 kW	11-7-77
Turkey	59	Technical University of Istanbul Istanbul	TRIGA Mark II	250 kW	250,000 kW	3-11-79
Viet Nam	60	Institute of Nuclear Research Dalat	TRIGA Mark II	Decommissioned		2-26-63
Yugoslavia	61	Jozef Stefan Nuclear Institute Ljub jana	TRIGA Mark II	250 kW		5-31-66
Zaire (Congo)	62	Nuclear Science Commission Kinshasa, Zaire	TRIGA Mark II	1,000 kW	1,000,000 kW	5-27-59

ATTACHMENT D

MEMORANDUM

TO: Commissioner Gilinsky

FROM: Gerald L. Pollack

SUBJECT: Converting Argonaut Reactors at U. S. Universities to 4.8% LEU Fuel

DATE: February 8, 1984

There are five Argonaut reactors among the 25 university reactors that use HEU. These Argonaut reactors are at: Iowa State University (10 kW), University of California at Los Angeles (100 kW), University of Florida (100 kW), University of Washington (100 kW), and Virginia Polytechnic Institute (100 kW). All of these Argonauts now use 93.3% HEU fuel. The total authorized amount of ^{235}U for them is 29.9 kg.

Recent studies at the University of Florida show that these reactors could probably be converted cheaply and quickly to use fuel that is 4.8% LEU. This fuel is already available in good quantities, it is the SPERT fuel. The fuel is stored mostly at the University of Florida but there is also some at Rensselaer Polytechnic Institute. The fuel is unused and is available at no cost. The total amount of SPERT fuel is estimated as enough to fuel all of these Argonaut reactors for about 40 years.

These studies were done by Dr. Nils J. Diaz of the University of Florida reactor, with DOE support. Initial studies have determined that the conversion can be accomplished in principle, i.e. it seems to be easily feasible. The studies also indicate that the neutron flux for the University of Florida's reactor would increase by 80% if the 4.8% LEU conversion were carried out. Because of the similarities in design among the Argonauts, Dr. Diaz and his people can carry out a generic study of the feasibility and safety of this conversion for all five of the university Argonaut reactors. That additional study would not take long (less than a year) and would not be expensive (less than $100,000).

It is likely that some modifications would be necessary in some of the Argonauts in order to convert to 4.8% LEU. For example the fuel grids might have to be changed somewhat, tools to handle the new fuel may be needed, and thermal hydraulics and shielding modifications may be needed. Results so far show that these changes would probably be minor and inexpensive but that is not yet sure. Exactly what changes are required would soon be determined by the studies mentioned above.

Conclusion: The idea of converting Argonauts to 4.8% LEU is, in my opinion, sufficiently promising to deserve further study now by the NRC. Conversion may be done relatively quickly and cheaply and may apply to several reactors. Some concrete ordered steps are: (a) Complete the studies that have been initiated at the University of Florida. This is probably best done by Dr. Diaz with his people, who are interested in and well able to do these studies. (b) The next step is to convert, to 4.8% LEU using the existing SPERT fuel, those Argonauts which require only minor changes. This group should include most of the Argonauts; it may include them all. The earlier objections, of university reactor operators, to conversion to LEU would be well satisfied by this conversion since the costs and licensing problems would be small. (c) There might remain some Argonauts which require larger modifications for conversion to 4.8% LEU (the Virginia Polytechnic Institute reactor may be in this category). In that case the NRC may be able to help with any potential relicensing problems or, alternatively, the reactors could be converted to LEU fuel along with the other non-Argonaut reactors.

GP/paw

ATTACHMENT E

COMMITTEE TO BRIDGE THE GAP
1637 BUTLER AVENUE =203
LOS ANGELES, CALIFORNIA 90025
(213) 478-0829

October 29, 1984

Dr. Enzo Ricci
996 West Outer Drive
Oak Ridge, TN 37830

Dear Dr. Ricci,

We recently received a copy of your September 19, 1984 letter to Representatives Fuqua and Lloyd regarding the NRC proposed rule requiring conversion of domestic research reactors from weapons-grade fuel, and we were astounded at your comments. Several of your remarks appear to us to be in error (e.g., the amount of such material required to make an explosive device, the reduction in risk associated with conversion, etc.) But one of your statements is pure fantasy.

As part of your argument against the NRC proposal, you state that the Committee to Bridge the Gap

> has pledged to challenge all university and research reactors due for NRC relicensing. (page 3 of your letter)

This is preposterous. We have never made such a pledge. Even were such a campaign of mass interventions possible, which for legal and other reasons it probably is not, we have neither the desire nor the intention to undertake such a dubious project, and have never suggested otherwise. Indeed, over a dozen research reactors have been relicensed in the past year alone, without challenge from us or anyone else. It is irresponsible of you to have publicly stated as fact this outrageous fabrication.

Your larger concern that passage of the NRC rule, along with the license amendments which will likely be required, will lead to interventions and public hearings is easier to understand, but it is likewise mistaken. In fact, as explained below, the opposite is closer to the truth: It is continued use of highly enriched uranium (HEU) which will lead to public controversy.

In the first place, it should be recognized that there have been literally hundreds of license amendments to nonpower reactors in the last several years. They are routinely published in the Federal Register. Many amendments are for a change in reactor operation in the direction of increased risk, e.g. a tenfold increase in power. Yet there has never been a single intervention with regard to these amendments.

It is therefore practically unthinkable that license amendments to allow conversion to low enriched uranium (LEU) fuel will face interventions and public hearings, particularly since conversion will yield a more secure and in some cases a safer reactor, aside from its other benefits. Witness the fact that in the abundance of public comments on the NRC proposal, there is not a single expression of opposition to conversion from the general public. The public supports the measure, and is determined to see it implemented. And, for your information, the potential for intervention on any proposed amendment is limited by law to the scope of the amendment. In other words, one could not raise issues unrelated to conversion when challenging conversion amendments. Therefore, no full scale intervention as in the UCLA case is even conceivable with regard to such amendments. And again, there is no individual or organization that we know of who would possibly try to challenge conversion in and of itself.

Let me reiterate our own position. We will not intervene, nor would we assist others to intervene, to block conversion to LEU.

On the other hand, in light of the strong public support for conversion, one should consider the implications for nonpower reactors of rejection or weakening of the NRC proposal, e.g. to exclude reactors with lifetime HEU cores. In such an event, I believe, licensees that continue to use HEU will be overwhelmed by public controversy. Those facilities due for relicensing will likely face interventions. Others will face other sorts of pressures from their communities and institutions, as well as the possibility of legal action. Our review of the NRC dockets of nonpower reactors has revealed an abysmal state of security preparedness at many facilities, totally inadequate to protect special nuclear materials against a serious threat. And so we would in some instances find reason to support such public efforts.

In light of this situation, it appears that it is retention of HEU rather than conversion that will lead to greater stress on nonpower reactors, including the possibility of total shutdown. Aside from public concern, at least two factors lead independently to this conclusion. First, facilities which use or convert to LEU will be easier to relicense. This certainly would have been the case in the UCLA reactor proceeding, from which UCLA withdrew one week before the long-awaited hearings on security at the site unable, we think, to meet its burden of proof that it could adequately protect its HEU fuel.

Secondly, the NRC will ultimately require a substantial upgrading of security for those facilities continuing to use HEU, well beyond even the new security requirements the Staff is currently discussing. And unlike conversion, the cost of these measures will have to be borne by licensees, not by the government.

For these and other reasons, we believe that the interests of nonpower reactor licensees coincide with the NRC position represented by the proposed rule, and with the public will to reduce the use of HEU as far as possible.

In the future, if you require further clarification of our position, we invite you to contact us directly.

Sincerely,

Steven Aftergood

Steven Aftergood
Executive Director

cc: Rep. Don Fuqua
Rep. Marilyn Lloyd
A. Francis DiMeglio
Joseph M. Hendrie
Secretary of the NRC

ATTACHMENT F

September 22, 1983

MEMORANDUM TO: COMMISSIONER GILINSKY

FROM: GERALD L. POLLACK

SUBJECT: CONVERTING REACTORS AT ACADEMIC INSTITUTIONS FROM HEU TO LEU

There are 23 academic institutions in the U.S. which have reactors fueled with HEU. I have discussed with senior reactor administrators at each of these institutions the problems they foresee in converting their reactors to LEU.

The reactor administrators are generally in favor of the conversions to LEU and would be cooperative. They are also in agreement on the problems they anticipate, which are:

(1) The academic institutions and therefore the reactors are on tight budgets and could not afford to pay for the conversions. They are therefore all concerned that the cost of the new LEU fuel as well as the costs of removing, transporting, and reprocessing their present HEU cores would be borne by some U.S. government agency. After the conversion several measurements, recalibration, etc. must be made on the reactors. They would also like help to cover the costs of these.

(2) The reactor administrators are concerned that it would be expensive and time consuming to meet the NRC requirements for relicensing the reactors once they are converted to LEU. They would like this to be done as quickly, inexpensively, and as painlessly as possible.

(3) A less critical problem which concerns the reactor administrators is the timing of the conversions to LEU fuel. Since the reactors would have to be out of use during this period, they would like help in minimizing the down time and for pre-planning when the conversions would occur.

Naturally all of the reactor people are interested in how their reactor's properties would change if converted to LEU. The best information on this comes from current experiments at the University of Michigan's reactor in which LEU and HEU core-exchange experiments are underway. These experiments show that there are only small changes in reactor properties, viz. the neutron flux decreases by about 10% and the spectral distribution becomes a little harder.

Appended to this memorandum is detailed information which is germane to LEU conversion, for each of the 23 institutions. I have included information on the reactor type, location, authorized amount of U-235 , reactor administrator, President of the institution, NRC project manager, license status, uses of the reactor, present fuel and fuel use, and administrator's comments on conversion of the individual reactor to LEU. Since there was common concern with (1), (2) and (3) above, these have been omitted from the comments to avoid redundance.

This information is only the tip of an iceberg of available information on these reactors. The American Nuclear Society has published a volume entitled "Research, Training, Test and Production Reactor Directory, United States of America" (Second Edition, 1983) which contains a plethora of such information. The Nuclear Engineering Department Heads Organization (NEDHO) is preparing a detailed survey on conversion of these reactors and will report shortly to the NRC staff on this issue.

The reactors listed are, in order: Oregon State University, Washington State University, University of Wisconsin, Texas A. & M. University, Virginia Polytechnic Institute, University of Washington, University of Florida, University of California at Los Angeles, Iowa State University, University of Michigan, University of Lowell, Worcester Polytechnic Institute, University of California at Santa Barbara, University of Missouri (Rolla), University of Virginia, Purdue University, Georgia Institute of Technology, University of Kansas, Manhattan College, Ohio State University, Rensselaer Polytechnic Institute, Massachusetts Institute of Technology, and University of Missouri (Columbia).

There are still some limitations in converting these reactors to LEU even if the above-mentioned money, licensing, and timing problems are solved. The two largest reactors, M.I.T. and the University of Missouri (Columbia), may not be convertible to LEU with present technology. Some of the other reactors may require high-density silicide fuels if they are to be convertible to LEU. Fabrication techniques for such fuels are currently under active development in the RERTR program (Reduced Enrichment for Research and Test Reactors) at Argonne National Laboratory, at Babcock & Wilcox (Lynchburg), CERCA (France), and NUKEM (W. Germany).

Another consideration, but apparently not a serious limitation, is in providing casks in which to ship the spent HEU fuel for reprocessing. There are at least three such casks available now (one BMI-1 cask and two GE-700 casks) and there may be others. If more casks are needed, Battelle Columbus Laboratories which owns the BMI-1 cask can, for example, arrange to have some new casks manufactured.

Between the Savannah River and Idaho Falls plants, the technology for reprocessing LEU fuel is available. DOE is now examining the economic feasibility of reprocessing LEU fuel; they want to see if a marketable product results.

The main limitation in converting Materials Testing Reactors (MTR) to LEU is in the availability of LEU plate-type fuel. In the U.S. plate-type fuel is manufactured by Babcock & Wilcox. Babcock & Wilcox does now have the technology to produce oxide and aluminide LEU fuels. They are preparing to fabricate new LEU for the University of Michigan reactor. A necessary step in converting the MTR's to LEU is to arrange with B&W to provide the fuel.

LEU fuel availability for TRIGA reactors is fortunately not a limitation. Such fuel is now manufactured by General Atomic which has adequate production facilities to provide this fuel to convert the four university TRIGA reactors (Oregon State, Washington State, University of Wisconsin, and Texas A. & M.). These TRIGA reactors could be converted to LEU soon.

Conclusions:

Now would be a good time to move rapidly on converting university reactors to LEU since: (a) the reactor people are generally in favor, (b) NRC and DOE are seriously interested, and (c) most of the technical problems are solved or seem to be near solution.

A possible ordered plan for proceeding would be:

(A) Determine whether DOE would be willing to provide money to refuel these reactors. DOE/University and Industry Programs has close relations with the reactor administrators and would be a natural place to start.

(B) Determine which the NRC would be able to do to expedite relicensing of the converted university reactors. This would meet the common concerns of the reactor administrators as described in (2) above.

(C) Find out from Babcock & Wilcox, or perhaps from some other potential fuel fabricator, just what a reasonable production and delivery schedule for LEU would be. It will be necessary to know, for example, when oxide and aluminide LEU fuel could be manufactured, the cost, etc.

(D) Finally it is important to keep the reactor people themselves well informed on how DOE and NRC are proceeding and what is likely to happen. This will help the reactor administrators in their planning and in relations with their institutions. A good avenue for this communication is the National Organization of Test, Research and Training Reactors (TRTR). This organization has an annual meeting which is attended by reactor managers and directors (the next one is October 20-21, 1983 at M.I.T.). There are also meetings which are attended by reactor managers and directors in the international community (the next one is October 17-19, 1983 at M.I.T., the International Meeting on the Uses and Development of Research Reactors). It is important to keep the international community informed of progress in LEU conversions in order to help with converting their reactors.

Academic Institution:

Oregon State University, Corvallis, Oregon.

Reactor Type: TRIGA, 1 MW

Location of Reactor:

Radiation Center, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 16.3 kg

Reactor Administrator Contacted:

Director and Head of Nuclear Engineering Department,
C. H. Wang (503) 754-2341

President of Institution:

Dr. Robert MacVicar (503) 754-4133

NRC Project Manager: Robert E. Carter

License: Present license runs until 2006.

Uses of this Reactor:

This reactor is used for teaching and for research. Research uses are neutron activation analysis, radiography, nuclear chemistry, radiation protection applications, and nuclear physics.

Present Fuel and Fuel Use:

The core of this reactor is entirely 70% HEU, stainless-steel clad, TRIGA FLIP fuel, fabricated by General Atomic. Fuel is used at the rate of about 75 g of ^{235}U per year.

Comments on Converting to LEU:

This is a standard TRIGA reactor designed and constructed by General Atomic. If this reactor were converted to LEU, the power level, flux, and spectrum would be essentially unchanged but the pulsing properties would be limited. With the present HEU core it can pulse to 3000-9000 MW (6ms half-width) but with LEU it could pulse to a maximum of about 3000 MW.

Academic Institution:

Washington State University, Pullman, Washington

Reactor Type: TRIGA, 1 MW

Location of Reactor:

Nuclear Radiation Center, an on-campus research building.

Authorized Amount of ^{235}U: 19.9 kg

Reactor Administrator Contacted:

Assistant Director, W.E. Wilson (509) 335-8641

President of Institution: Dr. Glenn Terrell (509) 335-6666

NRC Project Manager: Robert E. Carter

License: Present license runs until 2002.

Uses of this Reactor:

This reactor is used for research in neutron activation analysis, isotope production, and biological and plant science applications.

Present Fuel & Fuel Use:

The core of this reactor is mixed 70% FLIP and 20% ^{235}U enrichment TRIGA fuel, stainless-steel clad, manufactured by General Atomic. Fuel is used at the rate of about 40-60 g of ^{235}U per year. They have enough fuel for about 15 years of operation.

Comments on Converting to LEU:

This reactor is an MTR which has been reconfigured to use TRIGA fuel. The University of Wisconsin and the Texas A. & M. reactors are essentially the same as this one.

If this reactor had to convert to LEU, they anticipate that they might close down the reactor. The main objections are to the potential expense and trouble of recalibrating and reoptimizing the reactor and in redoing the reactor code, on which 4-5 man years have been spent. The reactor administrator expects that converting this reactor to LEU would take a lot of work and would significantly affect its properties.

Academic Institution:

University of Wisconsin, Madison, Wisconsin

Reactor Type: TRIGA, 1 MW

Location of Reactor:

Mechanical Engineering building, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 13.65 kg

Reactor Administrator Contacted:

Director, R. J. Cashwell (608) 262-3392

President of Institution:

Dr. Robert M. O'Neil (608) 262-2321

NRC Project Manager: Robert E. Carter

License: Present license runs until 2000.

Uses of this Reactor:

This University has a Department of Nuclear Engineering and the reactor is used for teaching and research. The research is primarily neutron activation analysis (7,000-8,000 samples per year); also stable tracer work for animal feeding studies.

Present Fuel & Fuel Use:

The core of this reactor is entirely 70% HEU, stainless-steel clad, TRIGA FLIP fuel, fabricated by General Atomic. Fuel is used at the rate of about 35-50 g of ^{235}U per year. Under normal use this core is a lifetime supply of fuel.

Comments on Converting to LEU:

This reactor is an MTR which has been reconfigured to use TRIGA fuel. The Washington State University and Texas A. & M. University reactors are essentially the same as this one.

The expected changes in properties of this reactor if it were converted to LEU are not significant. The anticipated problems are the common ones in the covering memorandum.

Academic Institution:

Texas A. & M. University, College Station, Texas

Reactor Type: TRIGA, 1 MW

Location of Reactor:

Nuclear Science Center, an off-campus building used for research.

Authorized Amount of ^{235}U: 17.2 kg

Reactor Administrator Contacted:

Director, D. E. Feltz (409) 845-7551 and Head of Nuclear Engineering Department, C. A. Erdman (409) 845-4161

President of Institution:

Dr. Frank E. Vandiver (409) 845-2217

NRC Project Manager: Harold Bernard

License: Present license runs until 2003.

Uses of this Reactor:

This University has a Department of Nuclear Engineering and the reactor is used for teaching, research, and training power reactor operators. The research is neutron activation analysis, radiography, isotope production, and uranium analysis.

Present Fuel & Fuel Use:

The core of this reactor is entirely 70% HEU, stainless-steel clad, TRIGA FLIP fuel, fabricated by General Atomic. Fuel is used at the rate of about 110 g of ^{235}U per year. At current rate of use the core would last 7-10 years.

Comments on Converting to LEU:

This reactor is an MTR which has been reconfigured to use TRIGA fuel. The Washington State University and University of Wisconsin reactors are essentially the same as this one.

This reactor would welcome conversion to LEU and is apparently on a high priority for conversion from DOE/University Programs. They expect that the changes in reactor properties would not be significant. The best way to convert to LEU would be all at once rather than in stages.

Academic Institution:

Virginia Polytechnic Institute, Blacksburg, Virginia

Reactor Type: Argonaut, 100 kW

Location of Reactor:

Robeson Hall, the physics building, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 8.0 kg

Reactor Administrator Contacted:

Director, T. F. Parkinson (703) 961-6510

President of Institution: William E. Lavery (703) 961-6231

NRC Project Manager: Harold Bernard

License: In process of renewal.

Uses of this Reactor:

This University has a program in nuclear engineering in the Mechanical Engineering Department. The reactor is used for teaching, research (neutron activation analysis), and training.

Present Fuel & Fuel Use:

The core of this reactor is plate-type 90% HEU, Al clad, manufactured by American Standard. This reactor uses fuel at a low rate and they have a lot of new fuel on hand. They have enough fuel for about 20 years.

Comments on Converting to LEU:

This reactor has no objections to converting to LEU. The only anticipated problems are the common ones in the covering memorandum.

Academic Institution:

University of Washington, Seattle, Washington

Reactor Type: Argonaut, 100 kW

Location of Reactor:

Nuclear Reactor Laboratory, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 7.5 kg

Reactor Administrator Contacted:

Director, M. A. Robkin (206) 543-4170

President of Institution:

Dr. William Gerberding (206) 543-5010

NRC Project Manager: Harold Bernard

License: Present license runs until 1989.

Uses of this Reactor:

This University has a graduate Department of Nuclear Engineering. The reactor is used for teaching and for research, primarily neutron activation analysis.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type 93% HEU, Al clad, manufactured by Martin-Marietta. This reactor is used very little, and the fuel use is less than 1 g of ^{235}U per year. It has a lifetime core.

Comments on Converting to LEU:

In order to convert this reactor to LEU some redesigning may be necessary because of lack of space. The main problems they anticipate are the costs of contractor work (if necessary), safety analysis and relicensing, computation, etc.

Academic Institution:

University of Florida, Gainesville, Florida.

Reactor Type: Argonaut, 100 kW

Location of Reactor:

Reactor Building, an on-campus building with laboratories and offices.

Authorized Amount of ^{235}U: 4.82 kg

Reactor Administrator Contacted:

Manager, W. G. Vernetson (904) 392-1408

President of Institution:

Dr. Robert Q. Marston (904) 392-1311

NRC Project Manager: Harold Bernard

License: Present license runs until 2002.

Uses of this Reactor:

This University has a Department of Nuclear Engineering (graduate and undergraduate). The reactor is used for teaching, training, and research such as neutron activation analysis and neutron noise experiments.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type 93% HEU, Al clad, manufactured by Martin-Marietta.

Comments on Converting to LEU:

This reactor has enough 4.8% LEU fuel to completely refuel their reactor. This is the SPERT fuel. The reactor administration has some tentative plans to carry out this conversion but it's not clear whether this will actually be done. The SPERT fuel may need to be licensed. If this conversion were carried out the changes in reactor properties are expected to be small. However, shielding problems will change since the SPERT fuel is clad with stainless steel.

Academic Institution:

University of California, Los Angeles

Reactor Type: Argonaut, 100 kW

Location of Reactor:

Boelter Hall, an on-campus building with offices, student laboratories, and a classroom either in the building or attached to it.

Authorized Amount of ^{235}U: 5.0 kg

Reactor Administrator Contacted:

Manager, N. Ostrander (213) 825-2825

President of Institution:

Dr. Charles E. Young (213) 825-2151

NRC Project Manager: Harold Bernard

License:

Was due to expire on March 30, 1980. Hearings are on now.

Uses of this Reactor:

This University has a Department of Mechanics, Structures, and Nuclear Engineering. The reactor is used for teaching (graduates & undergraduates) and for research, mainly neutron activation analysis.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type 93% HEU, Al clad, manufactured by Martin-Marietta, Rockwell, or Atomics International. The fuel use is about 1 g of ^{235}U per year.

Comments on Converting to LEU:

This reactor's staff has done preliminary studies on how the reactor's characteristics would change if it were converted to LEU. They concluded that the changes would be negligible as long as the LEU fuel plates were the same shape and size as the present HEU fuel.

Academic Institution: Iowa State University, Ames, Iowa

Reactor Type: Argonaut, 10 kW

Location of Reactor:

Nuclear Engineering Laboratory, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 4.6 kg

Reactor Administrator Contacted:

Manager, R. A. Hendrickson (FTS 865-5840) and Supervisor, E. Plettner (FTS 865 -6422)

President of Institution:

Dr. W. Robert Parks (515) 294-2042.

NRC Project Manager: Harold Bernard

License:

Renewal now pending. If granted it will run to 2003.

Uses of this Reactor:

This University has a Nuclear Engineering Department. The reactor is used for teaching (graduates & undergraduates), for training people to operate reactors, and for graduate student research.

Present Fuel & Fuel Use:

The core of this reactor is plate-type HEU fuel, Al clad, manufactured by Sylcor. The fuel use is of the order of milligrams of ^{235}U per year; since 1959 less than 0.5 g of ^{235}U have been used.

Comments on Converting to LEU:

This reactor is in favor of converting to LEU. The only anticipated problems are the common ones in the covering memorandum.

Academic Institution:

University of Michigan, Ann Arbor, Michigan

Reactor Type: MTR, 2 MW, pool

Location of Reactor:

Phoenix Memorial Laboratory, an on-campus building used for research.

Authorized Amount of ^{235}U: 16.11 kg

Reactor Administrator Contacted:

Director, W. Kerr (313) 764-6223

President of Institution:

Dr. Harold Shapiro (313) 764-6270

NRC Project Manager: Harold Bernard

License: Present license runs until 1985.

Uses of this Reactor:

This University has a Nuclear Engineering Department, graduate and undergraduate. The reactor is used for thesis research, neutron activation analysis, radiography, isotope production, and industrial testing.

Present Fuel & Fuel Use:

This reactor now has at least one complete LEU core and one complete HEU core; the cores are virtually identical in geometry. Both fuels are Al clad, the HEU fuel was manufactured by Babcock & Wilcox and the LEU fuel was manufactured by Atomics International, CERCA or NUKEM. Fuel use is 500-600 g of ^{235}U per year.

Comments on converting to LEU:

This reactor has no objection to converting to LEU and is row carrying out core-exchange experiments aimed at studying the changes in reactor properties which come about in going from HEU to LEU. They have so far found that in going to LEU, about 10% of the neutron flux is lost and the neutron energy spectrum becomes a little harder. For most applications these are not important effects.

Academic Institution:

University of Lowell, Lowell, Massachusetts

Reactor Type: MTR, 1 MW, pool

Location of Reactor:

Pinanski Building, on-campus. This reactor has a containment, contiguous to it is a building with classrooms and laboratories.

Authorized Amount of ^{235}U: 4.8 kg

Reactor Administrator Contacted:

Supervisor, T. Wallace (617) 458-9081

President of Institution:

Dr. William Hogan (617) 452-5000, x2201

NRC Project Manager: Harold Bernard

License: Present license runs until 1985

Uses of this Reactor:

This University has a Nuclear Engineering Department, graduate and undergraduate, and a Radiological Sciences Department, graduate and undergraduate. The reactor is used for teaching and for research such as neutron activation analysis, dosimetry, and electronic component testing.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type 93% HEU, Al clad, manufactured by United Nuclear or Atomics International. Fuel use is 20-25 g of ^{235}U per year. They'll need fuel soon and 12 new fuel elements for this reactor are now at Babcock & Wilcox.

Comments on Converting to LEU:

This is a sister reactor to the one at the University of Michigan and so it could be converted to LEU if fuel were available. The only anticipated problems are the common ones in the covering memorandum. They feel that to get ideal use of the present fuel they could gradually convert from the present core to a complete LEU core.

Academic Institution:

Worcester Polytechnic Institute, Worcester, Massachusetts

Reactor Type: MTR, 10 kW, pool

Location of Reactor:

Washburn Laboratory, an on-campus materials-science building used for teaching.

Authorized Amount of ^{235}U: 4.0 kg

Reactor Administrator Contacted:

Director, L. Wilbur (617) 793-5688

President of Institution:

Edmund T. Cranch (617) 793-5200

NRC Project Manager: Harold Bernard

License: Present license runs until 2002.

Uses of this Reactor:

The nuclear reactor studies program is an option in several engineering departments. The reactor is used exclusively for teaching and training.

Present Fuel & Fuel Use:

The core of this reactor is the original flat plate-type 93% HEU, Al clad, manufactured by General Electric. The reactor is used for a few hours each week and total fuel use has been about 0.4 g of ^{235}U in 20 years of operation.

Comments on Converting to LEU:

This entire reactor is a two-person operation and they are particularly concerned with the potential costs of conversion. If the conversion were to cost the Institute any money, then they'd probably shut down the reactor. According to the NRC-OPE report, this reactor could convert to aluminide LEU fuel.

Academic Institution:

University of California, Santa Barbara

Reactor Type: Homogeneous L-77, 10 W

Location of Reactor:

Broida Hall, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 1.35 kg

Reactor Administrator Contacted:

Director, A. E. Profio (805) 961-3412

President of Institution:

Dr. Robert Huttenback (805) 961-2231

NRC Project Manager: Harold Bernard

License: Present license runs until 1994.

Uses of this Reactor:

This University has a Department of Chemical and Nuclear Engineering (graduate & undergraduate). The reactor is used for teaching in this Department.

Present Fuel & Fuel Use:

This reactor has a liquid core, which is an aqueous solution of 89% HEU uranyl sulfate, manufactured by Atomics International. This reactor has a low-duty cycle and therefore uses very small amounts of ^{235}U.

Comments on Converting to LEU:

This reactor has no objection to converting to LEU. Their main concerns are the common ones in the covering memorandum.

This reactor can be converted to LEU and there would be no important changes in the reactor's characteristics. The same model of Atomics International reactor has already been operated with LEU.

Since the fuel is liquid the conversion probably involves pumping out the reactor, storing and shipping the fuel in several containers, and pumping in fresh LEU fuel. The new fuel solution must meet certain purity conditions, such as low chloride concentration, to avoid corrosion.

Academic Institution:

University of Missouri, Rolla, Missouri

Reactor Type: MTR, 200 kW, pool

Location of Reactor:

Nuclear Reactor Building, on-campus building used only for reactor staff.

Authorized Amount of ^{235}U: 7.0 kg

Reactor Administrator Contacted:

Director, A. E. Bolon, (314) 341-4720

President of Institution:

Dr. Joseph N. Marchello, (314) 341-4116

NRC Project Manager: Robert E. Carter

License:

Renewal now pending. If granted it will run to 2003.

Uses of this Reactor:

This University has a Department of Nuclear Engineering, graduate and undergraduate. This reactor is used primarily for teaching in 3 courses, including reactor operator training.

Present Fuel & Fuel Use:

The core of this reactor is curved plate-type 89-93% HEU, Al clad, manufactured by Curtiss-Wright. The fuel is somewhat unique in that it is a dispersion of U_3O_8 in Al. Fuel use is about 1 g of ^{235}U per year; they have a lifetime supply.

Comments on Converting to LEU:

This reactor could be converted to LEU and the changes in properties would not be significant. Their only concerns are the common ones in the covering memorandum.

Academic Institution:

University of Virgina, Charlottesville, Virginia

Reactor Type: MTR, 2 MW, pool and Cavalier 100 W

Location of Reactor:

Nuclear Reactor Facility, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 17.6 kg

Reactor Administrator Contacted:

Director, J.S. Brenizer, (804) 924-7136

President of Institution:

Dr. Frank L. Hereford, Jr., (804) 924-3337

NRC Project Manager: Robert E. Carter

License:

Present license for 2 MW runs until 2002. Cavalier comes up for renewal in about a year.

Uses of this Reactor:

This University has a Department of Nuclear Engineering and Engineering Physics. The nuclear engineering program is graduate and undergraduate. The Cavalier reactor is used for teaching. The MTR is used for teaching and research, mostly metallurgical studies but also neutron activation analysis and radiography.

Present Fuel & Fuel Use:

The cores of both reactors are plate-type 93% HEU, flat and curved, Al clad, manufactured by Atomics International. Fuel use is about 300 g of ^{235}U per year.

Comments on Converting to LEU:

According to the NRC-OPE report, fuel conversion must await development of medium-density oxide fuel. The staff of the reactor needs more technical information to determine how conversion to LEU would affect the properties of the reactor. However, they report that their research work, with the 2 MW reactor, does depend in an important way on the energy and flux.

This reactor's administration is especially concerned with the potential troublesomeness of relicensing once it is converted to LEU.

Academic Institution:

Purdue University, West Lafayette, Indiana

Reactor Type: MTR, 1 kW, pool

Location of Reactor:

Electrical Engineering building, an on-campus building used for research and teaching.

Authorized Amount of ^{235}U: 3.0 kg

Reactor Administrator Contacted:

Supervisor, E. R. Stansberry, (317) 494-5764

President of Institution:

Dr. Steven C. Beering, (317) 694-9708

NRC Project Manager: Robert E. Carter

License:

Present license runs until 1986.

Uses of this Reactor:

This University has a School of Nuclear Engineering, graduate and undergraduate. The reactor is used for teaching.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type 93% HEU, Al clad, manufactured by Babcock and Wilcox. In 21 years of operation the total fuel used is less than 0.02 g of ^{235}U. They have a lifetime core.

Comments on Converting to LEU:

According to the NRC-OPE report this reactor could convert to aluminide LEU fuel. In addition, senior engineering students at Purdue did a study of convertability and also concluded that this reactor could be converted to LEU. How the conversion would affect the reactor's properties isn't yet really known; more technical information is needed.

They are particularly concerned that the LEU fuel have the same dimensions as the present fuel so that rebuilding of the reactor wouldn't be needed.

Academic Institution:

Georgia Institute of Technology, Atlanta, Georgia

Reactor Type: MTR, 5 MW, tank

Location of Reactor:

Neely Nuclear Research Center; a reactor containment with an adjoining research and teaching building.

Authorized Amount of ^{235}U: 13.5 kg

Reactor Administrator Contacted:

Director, J. L. Russell, Jr., (404) 894-3620

President of Institution:

Dr. Joseph Pettit, (404) 894-5051

NRC Project Manager: Robert E. Carter

License:

Present license runs until 1994.

Uses of this Reactor:

This Institute has a School of Nuclear Engineering and Health Physics, graduate and undergraduate. The reactor is used for teaching, for operator training, and for research such as neutron activation analysis, radiography, and cancer therapy.

Present Fuel & Fuel Use:

The core of this reactor is curved plate-type, 93% HEU, Al clad, manufactured by Babcock and Wilcox. Fuel use is variable; it's now about 20 g of ^{235}U per year.

Comments on Converting to LEU:

This reactor uses heavy water as a moderator. It is likely the only heavy water reactor in current use at a university, so there are some special considerations in converting this reactor to LEU. According to the NRC-OPE report, conversion of this reactor must await development of silicide LEU fuel. The Georgia Tech reactor people haven't yet done the calculations themselves but they expect that the additional ^{238}U would have a large effect and that the thermal flux might decrease by 30-40%. Some of the medical applications of this reactor do depend on the flux level and they therefore might want to build a flux trap for the converted reactor.

They are especially concerned about potential problems in relicensing their reactor after conversion since it would be a unique case.

Academic Institution:

University of Kansas, Lawrence, Kansas

Reactor Type: MTR, 10 kW steady state, 250 kW maximum, pool

Location of Reactor: Nuclear Reactor Center, an on-campus building used for teaching and research.

Authorized Amount of ^{235}U: 4.0 kg

Reactor Administrator Contacted:

Supervisor, R. Mesler, (913) 864-3938

President of Institution:

Dr. Gene A. Budig, (913) 864-3131

NRC Project Manager: Harold Bernard

License:

Renewal non pending. If granted it will run to 2003.

Uses of this Reactor:

This University has a Health Physics program, graduate and undergraduate, and a Radiation Biophysics program. The reactor is used mainly for teaching.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type, 90% HEU, Al clad. The fuel was obtained from Bendix and the original fabricator may be Numec. Fuel use has been a total of 2-5 g of ^{235}U in about 20 years. They have a lifetime core.

Comments on Converting to LEU:

According to the NRC-OPE report, fuel conversion of this reactor must await development of silicide LEU fuel. It is expected that if the reactor were converted to LEU, there would be no significant changes in its properties.

This reactor is a low priority at the University and if they had the money to decommission it they might do it. Even if money were provided for removing the present HEU core and replacing it with an LEU core, the University would probably close down the reactor.

Academic Institution:

Manhattan College, Riverdale, New York

Reactor Type: Critical Facility 0.1 W

Location of Reactor:

Leo Engineering building; this building has offices, classrooms, and laboratories.

Authorized Amount of ^{235}U: 3.2 kg

Reactor Administrator Contacted:

Director, R. S. Kane, (212) 920-0144

President of Institution:

Br. Stephen Sullivan, (212) 920-0301

NRC Project Manager: Harold Bernard

License:

Renewal now pending. If granted it will run to 2003.

Uses of this Reactor:

This College has a Nuclear Engineering program in the Mechanical Engineering Department. The reactor is used for teaching.

Present Fuel & Fuel Use:

The core of this reactor is rod-type, 92% HEU, Al clad, manufactured by Sylcor. The reactor is used for only a couple of hours each semester. They have a lifetime core.

Comments on Converting to LEU:

This is an old, very low-power, reactor originally made by American Machine Foundry (AMF). It operates with a small staff. According to the NRC-OPE report the fuel conversion status of this reactor is not known. The reactor's staff feels that it would be extremely difficult, perhaps impossible, to achieve criticality with LEU fuel.

The reactor's staff is opposed to converting this reactor to LEU. They argue that because their power, staff, and usage are so small, the investment of the necessary time and money would not be worthwhile. If they had to convert to LEU, they'd stop the reactor program. They further point out that closing the reactor would be unfortunate since it is the only one in New York City.

Academic Institution:

Ohio State University, Columbus, Ohio

Reactor Type: MTR, 10 kW, pool

Location of Reactor:

Reactor Laboratory Building, not on main campus, used for teaching and research.

Authorized Amount of ^{235}U: 4.6 kg

Reactor Administrator Contacted:

Director, D. W. Miller, (614) 422-7979

President of Institution:

Dr. Edward H. Jennings, (614) 422-2424

NRC Project Manager: Harold Bernard

License:

Present license runs until 2000.

Uses of this Reactor:

This University has a Nuclear Engineering program in the Department of Mechanical Engineering, graduate and undergraduate. The reactor is used for teaching and for research, such as neutron activation analysis and reactor instrumentation testing.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type, 93% HEU, Al clad, manufactured by Texas Instruments. Fuel use has been less than 1 g of ^{235}U in 20 years.

Comments on Converting to LEU:

According to the NRC-OPE report this reactor could convert to oxide LEU fuel.

If this reactor were to convert to LEU, the reactor's staff would like to upgrade the power to 100 kW or more. This University has a new faculty member who is knowledgeable about LEU fuel and they would use his guidance for the conversion. They estimate that their core configuration could handle about 250 kW.

Their main concerns are the common ones in the covering memorandum.

Academic Institution:

Rensselaer Polytechnic Institute, Troy, New York

Reactor Type: Critical Facility, 100 W

Location of Reactor:

This reactor is in a separate building on G.E. grounds, off-campus.

Authorized Amount of ^{235}U: 10.9 kg

Reactor Administrator Contacted:

Director, D. R. Harris, (518) 270-6407

President of Institution:

Dr. George Low, (518) 270-6211

NRC Project Manager: Harold Bernard

License:

Renewal now pending. If granted it will run to 2003.

Uses of this Reactor:

This Institute has a Department of Nuclear Engineering, graduate and undergraduate. The reactor is used mainly for teaching in a course which students rate as the best one they take.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type, 93% HEU, stainless-steel clad. This reactor is normally operated at a very low level so fuel use is very low.

Comments on Converting to LEU:

This reactor could convert to LEU and the reactor staff would welcome the conversion. The staff has studied reconfiguring their reactor as part of a M.S. thesis [Ref. "Reconfiguration of RPI Critical Facility, by P.R. Nelson and D. R. Harris, Nuclear Technology 60, 320 (1983)]. No operational function would be changed if the reactor were converted to LEU; in fact the properties might be improved.

Their only concerns are the common ones which are mentioned in the covering memorandum.

Academic Institution:

Massachusetts Institute of Technology, Cambridge, MA

Reactor Type: MTR, 5 MW, tank

Location of Reactor:

Northwest 12, an on-campus building used for teaching and research. This reactor has its own containment.

Authorized Amount of ^{235}U: 29.0 kg

Reactor Administrator Contacted:

Operations Director, L. Clark, Jr., (617) 253-4202

President of Institution:

Dr. Paul E. Grey, (617) 253-4665

NRC Project Manager: Harold Bernard

License:

Present license runs to 1996.

Uses of this Reactor:

This Institute has a Department of Nuclear Engineering, graduate and undergraduate. The reactor is used for a lot of research and teaching. Many departments at MIT, many other educational and research institutions, and several industries and hospitals also use this reactor.

Present Fuel & Fuel Use:

The core of this reactor is flat plate-type, 93% HEU, Al clad, manufactured by Gulf United Nuclear, Atomics International, or Babcock and Wilcox. Fuel use is about 5.4 kg of ^{235}U per year.

Comments on Converting to LEU:

This reactor's staff feels that they couldn't convert it to LEU with present technology. They estimate that in order to go to LEU, a fuel with uranium density of about 8.5-8.7 g/cm^3 would be needed. It is not yet known how to fabricate such fuels, even using silicide. The reason for the problem is that this reactor uses state-of-the-art maximum HEU fuel loading and thermal hydraulics. They therefore do not have the flexibility that some other reactors enjoy.

However, if suitable LEU fuel could be fabricated then they expect their reactor's properties would change only in unimportant ways. In that case they would be willing to go to LEU and their only concerns would be the common ones in the covering memorandum.

Academic Institution:

University of Missouri, Columbia, Missouri

Reactor Type: ATR (Advanced Test Reactor) 10 MW, pressurized water vessel in a pool

Location of Reactor: Research Reactor Facility, an on-campus building used for research. This reactor has its own containment.

Authorized Amount of ^{235}U: 45.0 kg

Reactor Administrator Contacted:

Associate Director, D. Alger, (314) 882-4211

President of Institution:

Dr. Barbara S. Uehling, (314) 882-3387

NRC Project Manager: Robert E. Carter

License:

Present license runs to 2001.

Uses of this Reactor:

This reactor is used mainly for student and faculty research. Many department of the U. of Missouri, many other universities, industrial and government organizations use this reactor.

Present Fuel & Fuel Use:

The core of this reactor is curved plate-type ATR fuel, 93% HEU, Al clad, manufactured by Atomics International. Fuel use is about 4 kg of ^{235}U per year from MW-days of energy produced. (However 24 fuel elements cycle through the reactor each year and these each contain 0.775 kg of ^{235}U = 18.6 kg of ^{235}U cycled through.)

Comments on Converting to LEU:

According to the NRC-OPE report fuel conversion of this reactor must await development of silicide fuel. The Associate Director of this reactor reports that there is no possibility of going to LEU because the reactor is so compact. If fuels were available with uranium densities of 5-6 g/cm^3 then they could get adequate performance at 60-70% enrichment of ^{235}U. This is the highest power and flux university research reactor in the U.S. and the hardest case in terms of convertability to LEU.

[illegible] PR-50
(49 FR 27769)
(115)

ALAN CRANSTON
CALIFORNIA

137

United States Senate
WASHINGTON, D.C. 20510

November 1, 1984

[illegible] -2 A11:19

Office of the Secretary
Docketing and Service Branch
Nuclear Regulatory Commission
1717 H Street, N.W.
Washington, D.C. 20555

Dear Mr. Secretary,

Attached is a copy of a letter to Mr. Nunzio J. Palladino, regarding NRC's pending proposal to eliminate the use of high-enriched uranium in nuclear reactors.

I also submit it to your office as public comment being accepted in regard to the pending proposal.

Sincerely,

Alan

Alan Cranston

Acknowledged by card 11/2/84 pd

ALAN CRANSTON
CALIFORNIA

United States Senate
WASHINGTON, D.C. 20510

November 1, 1984 -2 A11:20

Mr. Nunzio J. Palladino
Chairman
Nuclear Regulatory Commission
1717 H Street, N.W.
Washington, D.C. 20555

Dear Joe,

I'm writing to voice my strong support for the Nuclear Regulatory Commission's pending proposal requiring nuclear reactors to switch to low-enriched uranium (LEU) from the high-enriched uranium (HEU) currently in use. As you are aware, I've been deeply concerned about the risks of nuclear proliferation for many years.

In my view, the pending proposal is eminently sensible. With the development of LEU replacement fuels, continued use of HEU in nuclear reactors presents a national as well as international security risk and a temptation for terrorists that should be removed. It would be a terrible tragedy to wait until the danger materializes, rather than eliminating the risk now.

It is simply blind-sighted to continue to permit weapons-grade uranium to be stored and used in areas of minimal security when reactors can now be converted relatively inexpensively to LEU fuels that can't be used to make bombs, but will run the reactors just as well. America's commitment to eliminate the threat of nuclear terrorism and to help stop nuclear proliferation must be demonstrated in both words and action.

I'm delighted that the NRC has made this well-thoughtout proposal to eliminate the use of HEU in nuclear reactors and urge its prompt adoption.

Cordially,

Alan

Alan Cranston

cc: Mr. S. Afterfood, CBG
Office of the Secretary,
NRC, Docketing & Service
Branch

DOCKET NUMBER PR-50
PROPOSED RULE
(49 FR 27769)

(119)

TEXAS ENGINEERING EXPERIMENT STATION
THE TEXAS A&M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS 77843-3575

NUCLEAR SCIENCE CENTER
409/845-7551

1 November 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Attn: Docketing and Service Branch

Reference: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (Fed. Reg. Vol. 49, No. 131, p. 27769, July 6, 1984 and Vol. 49, No. 158, p. 32369, August 14, 1984)

Gentlemen:

Texas A&M University, which operates a 1 Mw TRIGA research reactor using FLIP TRIGA "High Enriched Uranium" (HEU) fuel, respectfully submits comments on the above referenced proposed rule, the contents of which would affect our facility operations. Our involvement and subsequent comments on this subject date back to September 1983 when Commissioner Gilinsky included our facility in a survey on "Converting Reactors at Academic Institutions from HEU to LEU". The major concerns of the research community expressed at that time still exist, and they have since been discussed in detail at pre-rulemaking proceedings, at professional meetings, and in surveys conducted by special study groups, the USNRC, the DOE and Commissioners. Comments generated by the research and test reactor community have been summarized and documented by organizations such as the Test, Research, Training Reactor (TRTR) Managers, the American Nuclear Society ANS 15 Committee on Standards for Research Reactors, the American Council on Education, the Nuclear Engineering Department Heads Organization (NEDHO), and by the responses of test and research reactor owners/operators. Since these concerns are well documented, they will not be expanded upon in our comments; however, we feel it appropriate to again list those concerns that should receive serious review by the NRC Commissioners.

1. A major concern is how the proposed LEU conversion program is to be funded. Universities cannot assume the expense for new fuel, shipping expense to relocate present HEU fuels, expense of license material preparation, reimbursement for loss of non-university income due to the interruption of sponsored research, industrial research and commercial activities, and the expense for staff time and material costs to install and test the new LEU cores.

Acknowledged by card 11/6/84 pd

2. There is concern that licensing by the NRC cannot be done in a timely manner and that it will be difficult to avoid open hearings involving the general public. This would open the flood gates to interveners.

3. The LEU conversions must be technically feasible, and the new LEU fuels must be acceptable to the owner/operator and not only to the NRC as stated in the proposed rule.

4. Lifetime cores and long life cores presently using HEU fuel should not be required to change to LEU. This is based on sound and meaningful financial considerations.

5. There should be documented results of the performance testing of LEU fuels and the Reduced Enrichment for Research, and Test Reactors (RERTR) program should be complete prior to undertaking such a time consuming and expensive program. At present the RERTR program is not complete which presents the argument that the proposed rule puts the "cart" ahead of the "horse".

6. There is concern that nuclear related educational programs will suffer setbacks if universities find it too costly to convert their HEU fueled reactors to LEU and decide to shutdown. This could impact teaching and basic research activities on a national scale.

7. There is the concern that immediate enforced conversion will reinforce the incorrect *public image* of research reactors generated by Commissioner Gilinsky that we have "Nuclear Explosive Fuels" at some 22 university reactors.

8. There is concern that there is an absence of standards and guidance criteria to be applied by the NRC in the conversion of research and test reactors from HEU to LEU fuels.

9. There is concern that the actions required of domestic test and research reactors proposed in the rule will not influence foreign governments to follow our lead. Such governments ignored us in stopping commercial reprocessing and the Breeder Reactor Program. We can only encourage them to follow. If we overreact and take great measures to "show our good side", the end result most likely will be another setback to our national nuclear program.

As leaders of the nuclear engineering community here at Texas A&M, we wish to go on record as opposing the proposed rule, and we request that considerations for approval and implementation of the rule be halted. We make this request not only for the concerns listed above, but for an even greater concern we have in the application of the proposed rule to the operation of our TRIGA reactor. We question the technical feasibility of the new TRIGA LEU fuels in pulsing applications based on the fact that the RERTR program does not include the testing of TRIGA LEU with high burnup. This is critical to the reactor program at Texas A&M as well as several other universities. We are concerned that under the proposed terms of NRC acceptance of LEU fuels we could be forced to use a fuel system that would not meet our needs. We reference this concern to our experience with damage to FLIP TRIGA fuel in the NSCR in 1976. This damage occurred during pulsing, and it was concluded that the damage was directly related to an operating history where pulsing followed long periods of steady state operation (high burnup). We propose that G.A. Technologies conduct a pulse test program in conjunction with the RERTR Program to determine the limiting pulse fuel temperatures for high burnup TRIGA LEU fuels to prevent their damage if pulsed under similar operating conditions to those that resulted in damage to the HEU TRIGA fuel in the NSCR.

We appreciate the opportunity to comment on the proposed rule on "Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors", and we hope the Commissioners will carefully evaluate the concerns of the test and research reactor community and reach a decision to withdraw the proposed rule.

Sincerely,

Donald E Feltz

Donald E. Feltz, Director
Nuclear Science Center
Texas A&M University

Carl A. Erdman

Carl Erdman, Professor and Head
Department of Nuclear Engineering
Texas A&M University

cc: W. A. Porter, Director, Texas Engineering Experiment Station
J. Flipse, Associate Dean of Engineering and Vice Chancellor
H. Richardson, Dean of Engineering and Vice Chancellor

PROPOSED RULE PR-50
(49 FR 27769)
(124)

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

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ADLAI E. STEVENSON COLLEGE   SANTA CRUZ, CALIFORNIA 95064

'84 [illegible] -5 A11:09

November 1, 1984

Secretary Chilk
U.S. Nuclear Regulatory Commission
Washington, D. C 20555

Attn: Docketing & Service Branch

RE: HEU Rule (49 FR 27769)

Dear Secretary Chilk:

Please find enclosed for inclusion in the comment record for the HEU Conversion Rule the following two items:

1. RESOLVING THE SAFEGUARDS AND PROLIFERATION RISKS ASSOCIATED WITH PRESENCE OF WEAPONS-GRADE URANIUM AT RESEARCH REACTORS: Comments on the NRC's Proposed Rule to Convert Research Reactors from Weapons-Grade to Low-Enriched Uranium.

2. WEAPONS-GRADE URANIUM ON CAMPUS: The need to Convert Research Reactors to Lower Enrichment Fuels.

Sincerely,

Daniel Hirsch

Daniel Hirsch
Director
Adlai E. Stevenson
  Program on Nuclear Policy

BY EXPRESS

Acknowledged by card 11/6/84 pd

1896

DOCKETED

'84 [illegible] -5 A11:09

RESOLVING THE SAFEGUARDS AND PROLIFERATION RISKS ASSOCIATED WITH PRESENCE OF WEAPONS-GRADE URANIUM AT RESEARCH REACTORS

Comments on the NRC's Proposed Rule to Convert Research Reactors from Weapons-Grade to Low-Enriched Uranium

by
Daniel Hirsch
Director
Adlai E. Stevenson Program
on Nuclear Policy
University of California
at Santa Cruz
November 1, 1984

ANALYSIS OF NRC PROPOSED RULE TO CONVERT RESEARCH REACTORS FROM WEAPONS-GRADE URANIUM FUEL

Abstract

The U.S. Nuclear Regulatory Commission, in response to proliferation concerns about the use of Highly Enriched Uranium (HEU) both here and abroad, has published a proposed regulation that would require research reactors to convert to low-enriched, non-weapons-grade fuel. The proposal is a sound one, and, with certain modifications to ensure effective implementation, would have a salutory effect in the non-proliferation area both here and abroad.

The primary suggestions for improving the proposed rule deal with: (1) including a date certain in the rule by which conversion must be completed, (2) clarifying, or removing altogether, the language providing for possible exemptions from the rule and requiring, if exemptions remain possible, that they be extremely few and necessitating an affirmative vote by a majority of the NRC Commission.

The costs of not proceeding with the rule are tremendous: the risk of acquisition of a clandestine fission explosive, and detonation (or threat of detonation) of such a device, with the potential for tens of thousands of casualties, tens of millions of dollars of damages, and tremendous international instability. Furthermore, the cost of not going forward with the regulation would be the undermining of a long-held U.S. policy of attempting to eliminate HEU use abroad, for which the U.S. is a major supplier and where proliferation risks are very large. If domestic conversion does not occur--or its intent is bypassed by misuse of exemptions or failure to expeditiously implement conversion schedules--then foreign conversion will likewise be bypassed and delayed, causing tremendous injury to the U.S. goal of reducing proliferation risks worldwide.

The health of the U.S. nuclear community--both power and research reactors--is to a large measure dependent upon maintaining and making firmer the separation between civilian nuclear energy and nuclear weapons. LEU conversion is one of the few, internationally accepted, technical fixes that can permit continued functioning of reactors while reducing associated risks and potentially increasing public confidence. The regulation plays an important part in carrying forward long-held national and international policies as to minimizing proliferation risks by minimizing HEU use. The rule should be implemented, on an expedited schedule, with dates certain written in and exemptions that could become "loopholes" tightened up or taken out altogether.

> "We do have a nuclear threat in this country.
> It is very lucky if you have not had some problems."
>
> Robert Burnett, NRC Director of Safeguards, addressing research reactor operators regarding the threat of theft of highly enriched uranium at their facilities. [1]

> "...this is the type of material that could be used for a weapon and [if] it is attacked and removed from [a research reactor] site one night, or day, and I'm called up in front of Congress, saying, 'Burnett. don't you know better than that?' and I say. 'Yes. I do,' so I strongly suggest that you remove that incentive, that it is no longer economically for you a viable approach, and it is no longer an acceptable approach for us, either." [2]

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[1] Transcript of Safeguards Meeting with Nonpower Reactor Licensees, Glen Ellyn, Illinois, August 27, 1979, p. 52

[2] p. 74

ANALYSIS OF NRC PROPOSED RULE TO CONVERT RESEARCH REACTORS FROM WEAPONS-GRADE URANIUM FUEL

> The Nuclear Regulatory Commission (NRC) has licensing responsibility for domestic use and for export abroad of Special Nuclear Material, including High-Enriched Uranium (HEU), and is interested in reducing, to the maximum extent possible, the use of HEU in domestic and foreign research reactors.
>
> from NRC Policy Statement
> of August 17, 1982, "Use of
> High-Enriched Uranium (HEU)
> in Research Reactors"

Introduction

In keeping with its August 1982 Policy Statement and the long-standing national and international non-proliferation policy regarding minimizing "to the maximum extent possible" use of weapons-grade nuclear materials, the Nuclear Regulatory Commission has published a proposed rule that would require conversion of research and test reactors now using highly enriched (i.e., bomb-grade) uranium to low enriched fuel, not directly useable for making a nuclear weapon. *See* 49 FR 27769.

In explaining the purpose of the new rule reducing the enrichment of non-power reactor fuels, the Commission gave the following reasons:

> This reduction is desirable because HEU, in appropriate form and quantity, can be used to make an explosive device which can have severe adverse consequences on public health, safety and the environment. LEU has relatively little value for this purpose. The Commission believes that a new rule could reduce the risk of theft or diversion of HEU, could encourage similar actions by foreign operators of non-power reactors, and thereby, could reduce the amount of HEU in international use.
>
> *id*, at 27770

The proposed rule is thus very important in reducing non-proliferation risks from theft or diversion of weapons-grade nuclear materials, both at home and abroad, and an essential requirement in pursuing long-standing U.S. policy objectives, and those of the international community, with regards controlling the unique dangers associated with nuclear proliferation.

Background

Many research and test reactors use fuel thirty times as enriched as that used at power reactors, fuel that is, in fact, weapons-grade (i.e., directly useable in a nuclear weapon). These reactors thus pose a unique proliferation threat, because their fuel, if stolen or diverted, can be used to make a clandestine fission explosive.

Although a serious proliferation problem, this is one of the few for which there exists a sweet technical fix. Essentially all of these reactors can operate on low enriched uranium (LEU), material from which a nuclear weapon cannot be directly made. In fact, many of these reactors (e.g., the Argonaut) originally ran on LEU. Conversion involves replacement of HEU fuel with LEU fuel--the reactor continues to operate, but without the risk that its nuclear material could be stolen or diverted and a nuclear weapon fabricated therefrom, with all the attendant tremendous international ramifications that would ensue.

This proliferation solution--elimination of HEU use at non-power reactors by reducing HEU inventories and converting to LEU--has been one of the few widely accepted international and national proliferation policies. It is one to which this Government has been committed since the mid-1970s. As the Commission itself described the evolution of the concern:

> In the mid 1970's, particularly following India's detonation of a nuclear explosive device in 1974, nuclear proliferation concerns began to increase. Expanded efforts were undertaken to prevent nuclear power programs from being exploited to produce nuclear weapons. Particular concerns were expressed with respect to the proliferation risks associated with inventories of HEU for research and test reactors abroad. The widespread use of HEU fuel, which involved a large number of domestic and international fuel shipments, increases the risks of proliferation through theft or diversion of this material. In contrast to HEU, the use of fuel with lower enrichments reduces proliferation risks.
>
> 1982 Policy Statement on HEU

The Commission continued by saying, "In an effort to allay concerns of proliferation risks, efforts were made to reduce HEU inventories, on the assumption that any reduction in the potential for access to these inventories would constitute a reduction in the proliferation risk. These concerns eventually led to the establishment of the reduced enrichment for research and test reactor (RERTR) program."

In April, 1977, the Administration announced a policy to reduce proliferation risks by reducing the risk of theft or diversion of HEU, in part by moving to eliminate the use of HEU at research and test reactors worldwide. As part of that policy, DOE began the RERTR program, to develop replacement LEU fuels for non-power reactors. In 1978, Congress passed the Nuclear Nonproliferation Act, which further embodied the policy of reducing HEU use. And in 1980, the International Nuclear Fuel Cycle Evaluation (INFCE) endorsed the reduced enrichment policy. As the General Accounting Office Found in 1982, "The reduced enrichment program is one of the few concrete U.S. non-proliferation initiatives to gain widespread international support." (GAO Report ID-82-21).

As the Commission has itself stated, "The objectives of the RERTR program have been fully supported by NRC since its inception." (1982 Policy Statement). In 1979, the Commission deferred including research reactors in the Safeguards Upgrade Rule temporarily, while reduced enrichment fuels were being made available by RERTR, with the understanding that conversion to the LEU fuels when available would then reduce or eliminate the need for upgraded safeguards at these reactors. In 1982, the Commission issued its Statement of Policy, affirming its commitment to reduce "to the maximum extent possible" the use of HEU in use at domestic and foreign research reactors, concluding:

> The Commission notes that U.S. research reactor operators have shown little interest in converting to lower enrichment fuel. As part of a policy to strongly encourage conversion by foreign operators, the Commission will take steps to encourage similar action by U.S. research reactor operators. [3]

In 1983, a report prepared for the Commission (NUREG/CR-3666, "Assessment of the Implications of Conversion of University Research and Training Reactors to Low Enrichment Fuel,") informed the Commission that virtually all university reactors could convert to LEU with existing fuel technology, and in the 1984-1986 period, advanced fuels should be available to convert virtually all without even any plate spacing or channel thickness changes.

Updated schedules for qualification dates for replacement LEU fuels are included in Tables 1 and 2, below. Note that NUREG/CR-3666 indicates that only those reactors whose conversion would involve geometry changes would require a "major" license amendment. This would only affect 6 facilities today, and by next year fuel is to be qualified that would not necessitate any geometry changes, and thus no major license amendment would be necessary at all.

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[3] a footnote was appended by Commissioner Roberts, expressing concern that the steps were not being specified at that time.

Table 1 Current and Planned Fuel Technology

Number of University Reactors	Fuel Meat	Clad	Uranium Density in Fuel Meat (g/cc)		Planned Qualification Dates
			Current	Planned	
8 *	UAl_x-Al	Al	1.60	2.3	1984
4	UZrHx	Stainless Steel	.35	3.7	1984
2	U_3O_8-Al	Al	1.30	3.2	1985
4	U_3Si_2-Al	Al		4.8	1985 **
2 ***	U_3Si-Al	Al		7.0	1988

Source: NUREG/CR-3666, p. 18, updated with data from James Snelgrove's presentation on RERTR Program Progress at the TRTR meeting in Hamilton, Ontario, August 23-24.

** 2 of these reactors can apparently use the* Ual_x*-Al fuel qualified in 1984 or the* U_3Si_2*-Al fuel to be qualified next year.*

*** NUREG/CR-3666 indicates that these four reactors can convert to the 4.8 g/cc fuel, which Snelgrove reports is scheduled to be qualified in 1985; a 5.5 g/cc fuel is scheduled to be qualified in 1987, he indicates.*

**** MIT and Mo.-Columbia can convert to the 7 g/cc fuel, but their optimal fuel density would be 8.6 g/cc, which might necessitate a decision whether to convert to the 7 g/cc fuel, wait beyond 1988 for more advanced fuels, or converting to MEU of 30-40% enrichment.*

Table 2 REPLACEMENT LEU FUEL AVAILABILITY

I. With current fuel technology, all university research reactors in the United States, with the exception of MIT and the University of Missouri-Columbia, could convert now.

without geometry changes	with geometry changes
Michigan (already converted)	VPI
Ohio State	ISU
WPI	Georgia Tech
Purdue	UVAR
UF	Missouri-Rolla
UW	Va.-Cavalier
Lowell	6
RI	
Wisconsin	
Texas A&M	
Oregon State	
WSU	
12	

II. With advanced fuel technology, all could convert in the next few years without geometry changes.

FUEL QUALIFICATION DATES

1984	1985	1988+
Michigan	VPI	Mo.-Columbia
Ohio State	ISU	MIT
WPI	Georgia Tech	
Purdue	UVAR	
UF	Missouri-Rolla	
UW	Va.-Cavalier	
Lowell		
RI		
Wisconsin		
Texas A&M		
Oregon State		
WSU		
12	6	2

Notes: Taken from NUREG/CR-3666, pages 5, 18-20, modified to reflect current availability of LEU fuel for TRIGA reactors and updated by current fuel qualification dates presented by James L. Snelgrove of RERTR at the 1984 TRTR Meeting in Hamilton, Ontario. RPI and Manhattan, 1 x 10^{-4} and 10^{-7} MW respectively, for which no fuel density data were provided, were not included because reliable estimate of timeframe is dependent upon that data, although generally the lower the power the easier the conversion, so both should be able to convert in the near term. Decommissioning reactors removed from table. "Geometry changes" means changes in the number or thickness of fuel elements or coolant channels. MIT and Mo.-Columbia can convert to MEU (e.g., 30 or 40% enrichment, still a significant non-proliferation and safeguards step) in the near term. Lowell and RI included in 1984 because NUREG/CR-3666, p. 5, lists them as currently capable of converting without geometry changes; if one waits for advanced U_3Si_2 fuels, their fuels will be qualified a year later, in 1985.

With the program goals of RERTR, strongly supported by NRC since the inception of the reduced enrichment program, nearing completion by qualifying, or soon to be qualifying, non-weapons-grade replacement fuels for research reactors, the Commission took action to specify the steps it would take to carry out its 1982 Policy of using its regulatory and licensing authority to reduce "to the maximum extent possible" use of HEU in research reactors.

The Commission twice in 1984, first in February and then again in June, unanimously directed the preparation of a rule that would require conversion of all research reactors from HEU to LEU, unless a strong showing could be made that a unique research purpose could somehow not be carried out with the replacement LEU fuels, in which case one or two reactors would be exempted from converting to LEU, although they would be required to convert to as low an enrichment as possible (e.g., 30 or 40%). The Commission also directed the Staff to prepare on an expedited basis interim upgraded safeguards for these reactors while they converted to LEU, and asked for a reassessment of the validity of exempting from safeguards requirements fuel said to be irradiated at 100 Rem per hour or over, per fuel element, at 3 feet unshielded (the so-called "self-protecting" exemption.) The Commission called for a "reexamination of the technical basis for the present irradiation exemption and whether irradiation provides a sufficiently effective inherent safeguards protection for formula quantitie of SNM to justify the significantly lower level of physical protection associated with Category II." (Memo, Chilk to Dircks, "Development of a Proposed Rule on the Use of HEU and Steps to Improve Security Measures", February 23, 1984.)

Thus, after hearing extensively from the licensees who would be affected, as well as other interested parties, the Commission twice unanimously directed a rule be promulgated to require conversion of research reactors to non-weapons-grade fuels. The rule has been prepared and issued for public comment. There are thus only two issues: (1) has the rule been prepared as the Commission directed, and (2) is there new information in the public comments not previously considered by the Commission of sufficient weight and import as to cause it to reconsider its two previous unanimous determinations to move ahead on this matter, so long a matter of policy? The answer to the first question is a qualified "yes," although certain aspects of the rule are not quite as the Commission directed and should be modified (in particular, a fuzzy description of the "unique purpose" exemption that could become a very large loophole, undermining the Commission's intent for the rule, and, by a failure to include effective dates for conversion, not quite following through on the Commission's directive for expedition). As to the second question, none of the comments opposing the rule that have to date reached the docket (or been put forward in recent Congressional testimony) are anything but repetitions of objections previously put forward and rejected by the Commission in directing the promulgation of the HEU rule as it was eventually published. (It is interesting to note that the comments questioning the rule appear to come exclusively from a portion of the licensee community, whereas the public overwhelming supports the Commission's action.)

AREAS WHERE THE RULE NEEDS TO BE STRENGTHENED

1. The "Unique Purpose" Exemption Needs to be Tightened and Better Defined.

The Commission, in its directive to the Staff to draw up the rule, was quite explicit about what it wanted with regards the "unique purpose" exemption:

> Exemptions from this rule would be based on a determination that the particular reactor serves a unique purpose. Unique purpose should account for such characteristics as neutron flux levels and energy spectrum specifically designed to facilitate research on irradiations not performed elsewhere in the U.S.
>
> (emphasis added)

The Commission was quite clear about the very limited nature of the "unique purpose" exemption, that should a reactor be considered for an exemption from this important safeguards measure and implementation of national policy, the research it does must be unique--i.e., of substantial scholarly benefit, incapable of being performed with LEU or being performed elsewhere in the U.S.. The research must be sufficiently unique that it could not be done anywhere else in the U.S. and of sufficient importance that the risk of loss of the research for the nation outweighs the risk of theft of the HEU.

It was clear from all the Commission discussions that this exemption was considered to be extremely limited--for approximately one or two reactors only, such as MIT and University of Missouri-Columbia--and only upon a very strong showing.

Therefore, both the description of the "unique purpose" exemption in the statement of considerations and the definition contained in the text of the regulation itself should be rewritten. The language quoted above expressing the Commission's intent should probably be included directly.

The following should be included in the "unique purpose" definition, if that exemption is retained: (1) the research alleged to be no longer possible if the facility converts to LEU must indeed be unique--(a) not being performed elsewhere, (b) not possible to be performed elsewhere (i.e., by sending the irradiation sample, as is standard practice, for irradiation elsewhere, or by the research itself being performed elsewhere, (c) a substantial part of the research program of the facility (i.e., 25% or more; a reactor should not be permitted to avoid going to LEU on the basis of a single experiment or non-consequential minor aspects of its overall activities), and (d) the work is indeed unique, ie, of substantial scholarly benefit. (2) The unique research truly cannot be performed with LEU--(a) the experiment cannot be altered to accommodate the flux or spectral change, (b) the reactor cannot be operated differently

DOCKET NUMBER PR-50.
PROPOSED RULE (49 FR 27769) (128)

AMERICAN COUNCIL ON EDUCATION
Division of Governmental Relations

November 1, 1984

'84 NOV -9 A11:24

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attention: Docketing and Service Branch

Re: Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors (49 Fed. Reg. 27769)

Gentlemen:

On behalf of the American Council on Education, an association representing over 1,700 colleges, universities, and other organizations in higher education, and the associations listed below, we wish to respond to the proposed rule published on July 6, 1984, by the Nuclear Regulatory Commission to limit the use of highly enriched uranium fuel in domestic research and test reactors.

The NRC's proposed rule would affect both new and existing non-power reactors. New non-power reactors would be barred from using highly enriched uranium (HEU) fuel, fuel using uranium with an enrichment of 20% or greater, unless it could be shown that the reactors would have a "unique purpose," one which could not reasonably be accomplished without using HEU fuel. For non-power reactors currently authorized to use HEU fuel, the licensee would be prohibited from acquiring additional HEU fuel if low enriched uranium (LEU) fuel, fuel using uranium of less than 20% enrichment, acceptable to the NRC were available. The licensee would also be required to replace all its HEU fuel with LEU fuel on a schedule to be proposed by the licensee but determined by the NRC. Licensees could request NRC's permission to continue using HEU fuel upon a showing that the use of HEU fuel served a "unique purpose."

The NRC bases the need for the proposed rule on concerns over the risks that HEU material might be diverted. The higher education community strongly supports efforts by the Commission to reduce the risk of nuclear proliferation through the theft or diversion of HEU. However, we question whether the proposed rule would help to achieve this aim. We also question whether the proposed rule is not premature, in view of the federal government's ongoing program to explore the feasibility of converting existing reactors from HEU to LEU fuel. Finally, we suggest that the proposed rule would have serious financial and educational consequences for many colleges and universities, which in turn will adversely affect the nation's scientific and technical community.

No one can seriously challenge the need to take all reasonable steps to achieve the nuclear non-proliferation goals which underlie the proposed rule. However, the dramatic changes in the domestic use of HEU fuel proposed by the NRC appear to be aimed at encouraging similar actions by foreign reactor operations, rather than reducing an unacceptable risk from domestic non-power reactors. The NRC, in fact, points out in the Supplementary Information accompanying the proposed rule that domestic research and test reactors using HEU

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fuel "are operated without undue risk to the public health and safety." The Advisory Committee on Reactor Safeguards pointed out in its June 18, 1984, letter that the proposed rule is based on "an unidentified threat." If, as the NRC believes, the current use of HEU fuel in non-power reactors does not involve undue risks, why is any change needed? It is by no means obvious why a domestic "stick" should be used as a foreign "carrot." Nor has the Commission explained why, if HEU fuel in domestic non-power reactors somehow poses a risk, appropriate security measures would not be a suitable alternate protective strategy.

The higher education community also questions the timing of the proposed rule. Since the technical efforts to establish the workability of the rule are still in progress, consideration of the proposal at this time seems premature. The NRC points out in the Supplementary Information accompanying the proposed rule that the ability to convert non-power reactors to LEU is based on the Department of Energy's Reduced Enrichment for Research and Test Reactors (RERTR) program. However, that program has yet to be completed. In fact, the NRC states that it was encouraged to undertake this rulemaking proceeding by the "anticipated continued success over the next five years" of the RERTR program. While the NRC points out that information already developed indicates that "conversion of several non-power reactors from HEU fuel to LEU fuel is technically feasibile," the feasibility of coverting most of the remaining reactors can only be determined "if the goals of the RERTR program are successfully achieved over the next five years." Until the NRC has some better assurance that conversion is in fact technically feasible, it seems inappropriate to require licensees to submit conversion schedules and make commitments.

The prematurity of this proposal is also shown by the absence of standards and guidance to be applied by the NRC. For example, the proposed rule refers to replacing HEU fuel with LEU fuel "acceptable to the Commission." 50.64(c)(2)(i), 50.64(c)(2)(ii), 50.64(c)(3), and 50.64(d)(2). Nowhere does the proposed rule explain how the NRC will determine acceptability. Similarly, the proposal gives the Director of the Office of Nuclear Reactor Regulation no guidance to be used in determining the "final schedule" for conversion to LEU fuel. 50.64(d)(2). The NRC also indicates that an evaluation of reactor performance and safety aspects of conversion is underway, as is the possible development of generic envelopes of safety limits. Until the NRC completes its work on these important issues and makes the resulting reports and guidance available for comment, issuance of any final rule is premature.

Regarding the financial and educational consequences, the higher education community believes that implementation of the proposed rule may well result in the shutdown of at least some domestic research and test reactors using HEU fuel. Many institutions may not have the funding necessary to carry out the conversions. While some federal funding was made available in the Fiscal Year 1985 Department of Energy appropriations bill (P. L. 98-360), there is no assurance that future funding will be forthcoming. Furthermore, conversion to LEU fuel may involve significant licensing considerations, including the possibility of extended adjudicatory hearings. Licensing costs, whether direct financial expenditures, potential delays, or both, could cause some institutions simply to close down their reactors. These non-power reactors are clearly in the national interest, both in terms of scientific and technological research and innovation and of training personnel for the nuclear industry, personnel for which there is currently an acute shortage. Forcing the closure of domestic research and test reactors would thus be highly undesirable.

With these considerations in mind, the higher education community recommends that the proposed rule not be made final in its present form. While NRC licensees may properly be asked to bear the costs of modifying their facilities to meet safety concerns -- even including the costs of shutting down those facilities -- the lack of safety concerns with respect to domestic non-power reactors strongly argues against imposing these costs on licensees of such reactors using HEU fuel.

The college and university community greatly appreciates this opportunity to express its views on this proposal. We would be happy to meet with representatives of the Commission to discuss our concerns further. This letter is sent on behalf of:

American Council on Education
Association of American Universities
National Association of State Universities and Land-Grant Colleges

Very truly yours,

Sheldon Elliot Steinbach

Sheldon Elliot Steinbach
General Counsel

SES:gfr

DOCKET NUMBER PR-50
PROPOSED RULE (49 FR 27769)

(120)

[illegible] -5 P2:13

GA Technologies

GA Technologies Inc.
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SAN DIEGO, CALIFORNIA 92138
(619) 455-3000

LAW DEPARTMENT

November 2, 1984

Secretary of the Commission
Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Proposed Limitation of Highly Enriched Uranium in Domestic Research and Test Reactors

Dear Sir:

These are comments about the rule proposed in 49 Federal Register at page 27769.

Because GA Technologies has developed and demonstrated low-enriched uranium TRIGA (uranium zirconium-hydride) fuel at uranium levels up to 45 weight percent (3.7 gms/cc) and the fuel is now commercially available, it approaches NRC's proposed rule with divided feelings. It is GA's understanding that the development of LEU MTR-type fuel has not progressed so rapidly or so far. Naturally, GA would be pleased to sell its fuel for use in MTRs, at least some of which can be converted to TRIGA-type fuel, albeit that it is not such a simple matter as in TRIGAs. Commercial considerations aside, however, GA joins the rest of the research reactor community in pointing out that the proposed new regulation, if adopted, will be costly, will add nothing perceptible to public health and safety, may hamper training and medical applications by reducing the number of operating reactors, and will impede current research programs. It may waste a lot of fuel at a cost someone must bear, unless it is applied so as to allow essential exhaustion of current fuel inventories. In addition, the proposed rule is based on nothing more substantial than speculation about terrorists while the government is simultaneously admitting it is aware of no threats, and upon a wish to influence other nations. GA believes there is so little substantiated factual justification for the proposed rule that it can fairly be

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said to be arbitrary and capricious. It should not be adopted in its present form.

Before turning to some of the substance of the proposed rule, GA notes that most of the reactors that would be affected are owned by collegiate institutions. The mass of staff work underlying the proposed rule is laced with references to "university reactors". However, research reactors are also owned and operated by industrial organizations. Perhaps it was the industrial organizations NRC had in mind when executing its regulatory flexibility certification and asserting that the affected licensees do not fall within the definition of small businesses. It is true that they don't. The universities, however, are "small entities" and "small organizations" within the artificial definitions of the Regulatory Flexibility Act. See, for example, 5 U.S.C.A. 601(4) and 601(6). Since NRC can hardly certify that the proposed rule will not impose a prohibition upon a substantial number (i.e., all) of the statutory small entities or small organizations which own and operate "university reactors", in accord with 5 U.S.C.A. 604(a)(3) it should eventually publish a statement of the reasons why it rejected such alternatives as DOE's offer to store and safeguard unirradiated HEU fuel inventories for the reactor licensees. If only irradiated fuel need be considered because the unirradiated inventories are in DOE's hands, perhaps the Commissioners' assessment of the weight of the speculation about thieves would change.

The announcement of the proposed rule solicited comments about the economics of fuel conversion. Most of the responses NRC will receive will probably not refer to the economic value of the SNM contained in new fuel elements (and in those which would be thrown away in favor of the new) because most research reactor licensees are educational institutions. As such, they do not have to pay for the capital value of their uranium, since DOE does that for them. Industrial users have not been equally favored, and have to be concerned about the SNM value. In drafting the proposed rule NRC showed discomfort about the potential costs to both the university users and DOE facilities but ignored the cost to industrial licensees. That is entirely unfair, since to some extent the industrial and academic users are competitors of one another. More important, each class would be affected identically (each would have to get new fuel), by a new regulation based on impressions about the terrorist threat and reasons of international policy. Neither terrorists nor influencing other nations is relevant to the two licensee classes, and there should be no discrimination between them; if the government agencies waive their licensing fees and provide fuel in recognition of the effects of what they had done, they should do it for all licensees similarly affected.

Prices and costs to convert the high enriched fuel in GA's TRIGA can be realistically estimated:

1. New fuel for a 100-element core with spare fuel elements, spare thermocouple elements, spare fuel-follower elements (113 fuel elements at $11,610 each, $13,160 for fuel-follower control rods, and $15,350 per thermocouple element)	$1,395,270
2. Disposal costs.	
(i) Rental of BMI cask for three round trips -	about $30,000
(ii) Transportation with guards -	$75,000
(iii) Burial costs or reprocessing - including credit for SNM contents	about $200,000
3. Lost revenue: 2 months for $1.5 Million per year for the current thermionics program	$305,000
Total:	$2,005,270

Note that the estimated cost does not include expenses that might be encountered in litigation if there were opposition to a license change, nor the minimum of one man-year's work on the requisite SAR, but unlike the NRC estimates, this one accounts for the costs of disposing of HEU fuel. GA's recent experience shows that burial or reprocessing costs are substantial, and dwarf the transportation costs which were mentioned in the NRC analysis.

NRC said that any economic analysis by commentors should include estimates of the aversion of risk to the public health, safety, and the environment. GA's estimate is that there would be no risk averted by the $2,005,270.

It is fair to observe that there will probably be no valuable international influence exerted by it, either. Representatives of the European community have already indicated that their reactors will not be converted simply because of what happens to licensed reactors in the United States. It is unrealistic to expect otherwise. No doubt NRC will recall that in another situation when it attempted to influence the policies of other countries by throttling the reprocessing industry in the United States, the other countries paid no attention and went ahead with their reprocessing plans. Giving "a good example" may be an intriguing exercise and it may be a diverting subject for occasional debate in international relations, but it has had no desirable effect. Speculation about unidentified terrorists and uranium thieves in the United States and a desire to be a "good example" are too far removed from realpolitik to warrant imposing such substantial costs upon American licensees.

To cause only NRC-licensed facilities to bear costs to cease using HEU while no such practice is to be followed in the non-licensed reactors operated by government, where probably over 90 percent of the HEU consumed in the United States is concentrated, is even more unreasonable, and such a policy will surely not be persuasive in other countries.

NRC should bear in mind that its estimates of LEU replacement cores for universities do not include the cost of uranium. That is a cost industrial users would have to provide for in some way unless they get equal treatment, but even in the case of a university the taxpayers through DOE will be bearing the burden. Accordingly, when NRC arrays its own cost estimates for purposes of considering the rule, it should not omit the value of the uranium contents.

The published announcement and its supplementary information include no serious provision for avoiding or significantly mitigating the prolonged and largely pointless litigation that may well follow if a rule as presently drafted is set in motion. The staff correctly pointed out that LEU fuel can be used without license amendment to replace HEU if there is nothing to the contrary in a licensee's technical specifications and where 10 CFR 50.59 can be applied because the change presents no unreviewed safety question. It was unnecessary to mention Section 50.59, however; reactor licensees are well aware of it. The optimistic discussion of the effects and use of 50.59 is misplaced. The fact is that (at least for TRIGA reactors) it accomplishes nothing since

TRIGA reactor technical specifications stipulate the fuel that is to be used. GA is not intimately familiar with all the licenses, but believes that every TRIGA presently authorized to use HEU will be unable to apply 10 CFR 50.59 as a basis for substituting LEU fuel because the larger proportion of uranium to zirconium-hydride in the LEU fuel element will be a departure from the tech specs.

If NRC wishes to avoid licensee harassment in the license amendment process, it may be able to do so by promptly getting its generic analyses ready for use or perhaps by waiving the fuel density specifications, but a nod toward 10 CFR 50.59 will not do it.

GA wonders why it is not possible to establish a more reasonable definition of HEU than simply to draw a rough line at 20 percent enrichment. As GA understands it, fuel 50 percent enriched is unsuitable for even a terrorist bomb. DOE is believed to agree with that view. In the same vein, one has to wonder why credit cannot be given for the fact that uranium zirconium-hydride with burnable poison is harder to separate into its constituents than are the aluminide or oxide fuels. Those reflections, coupled with the fact that the "high enriched" TRIGA FLIP fuel is only 70 percent enriched, allow for a significant distinction between it and the oxide or aluminide fuels with their 93 percent enriched uranium. Objectively appraised, possibly TRIGA FLIP fuel would be seen to be no more attractive to the hypothetical thief than 20 percent enriched MTR fuel. To the extent that is so, use of the now-conventional 20 percent boundary without conscious and deliberate thought about its implications distorts the facts.

The proposed rule would require an immediate shift of procurement to LEU fuel (should any fuel be purchased) if suitable LEU fuel is available, followed by mandatory replacement of HEU with LEU on an NRC-approved schedule even if licensees had not otherwise planned to acquire replacement fuel. Apparently it was thought that more than a year would elapse before any suitable tested replacement fuel would be on the market. The staff overlooked or was unaware that TRIGA high uranium content LEU fuel has been available since 1978 and can be purchased. As drafted, the proposed rule would therefore require that TRIGA FLIP fuel replacement schedules be drawn soon and tendered to NRC within a year, even before the promised special NRC plans are in place to treat safety issues on a generic basis! Clearly, that should be corrected. One way to do it would be to specify that no licensee need replace presently approved fuel in the licensee's inventory until fuel has reached the end of its normal economic life.

At an earlier stage shortly before the Federal Register announcement, GA's President and the Manager of its TRIGA Reactors Facility wrote to the chairman and members of the Commission about their apprehension of the then-contemplated proposal. Those letters and their appended cost estimates are pertinent today so copies are enclosed as further comments.

Very truly yours,

J P Hogan

J. P. Hogan
Senior Counsel

Enclosures

GA Technologies Inc.
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19 June 1984

Dr. Nunzio J. Palladino
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Palladino:

I have tried unsuccessfully to reach you or your technical assistant, Dan Garner, to discuss troublesome aspects of the proposed rule on Conversion from HEU to LEU for non-power reactors. In this letter I have set forth considerations that I hope will be helpful to you in your deliberations. Under separate cover, President Agnew has sent letters individually to the other Commissioners whom he was able to contact directly this date.

We are quite concerned that this proposed rulemaking will fail in its espoused international objective and through incumbent costs, borne mainly by existing facilities (the order of $1-million or more per facility), will do great harm to the already beleaguered U.S. research community, consisting of government, university, and privately-owned facilities. We further believe that it is an unreasonable policy which causes only NRC licensed facilities, despite costs, to cease their utilization of HEU while no such requirement is mandated upon reactors operated by the government agencies.

It is paramount that NRC's policy for reducing enrichment in existing non-power reactor fuels follow these precepts.

1. Immediate conversion of HEU to LEU should not be required for existing U.S. reactors.

2. If and when a change to LEU is required, it should be done in moderate steps, e.g., at normal refueling periods, upon major facility upgrade involving core redesign, or at construction of a substantially new reactor facility, and

3. Licensees shall not be exposed to significant relicensing processes or associated costs as a result of replacing HEU fuels with LEU fuels to meet a national objective and shall be protected to the extent possible from intervenor actions.

We believe that precepts 1 and 2 should be NRC policy for a number of reasons.

(a) It is evident that no government agency or collective group has been or is now currently willing to fund directly the subject reactor conversions especially when considering the nebulous benefits and the pressing need for funds in other more tangible projects, many of which are carried out by universities throughout the nation; clearly reserve unirradiated HEU fuel should be kept in properly guarded storage.

(b) The HEU fuel in the reactor can be protected to the level required until it is normally replaced with LEU. The targeted 31 facilities all have some degree of access to campus police, local law enforcement agencies, or other armed forces.

(c) A substantial number of the faclities will be required to refuel with LEU in the normal course of operations. In the case of TRIGA reactors, no HEU fuels are expected to be available. Further, presuming NRC's initiative is supported by other government agencies, DOE should not responsibly supply HEU fuels to their facilities or to benefactor universities.

(d) It has been demonstrated by past rulemaking efforts that affected licensees are willing to provide required levels of physical protection to protect against the theft or diversion of a significant quantity of SNM.

On the latter point, licensees are justifiably apprehensive of the NRC position on the 100 Rem/hr at 3 ft "self-protection" limit for each and every fuel element when dozens of fuel elements are required to form a formula quantity. To prevent a facility from being construed as Category I (full protection required) when a single in-core fuel element falls below the above radiation limit, we recommend that the Commission promptly move forward with the completion of the previously published 10 CFR 73.67(d) rulemaking which allows the 100 Rem/hr self protection criteria to be averaged over a significant quantity of HEU (a quantity of one kilogram has been suggested). It is noteworthy that some licensees have placed additional locking devices around and over the reactor cores and that the added physical protection measures have involved a few tens of thousands of dollars rather than the $1-2 million required to convert a low power reactor to LEU fuel.

Precept 3 is required to protect the licensee against exceptional costs associated with licensing. The minimum licensing fee is $41,300 which is waived for universities but not for industrial, non-power reactor owners. The SAR to support a license change is costly both for universities and industrial owners and is estimated to require a man-year level of effort. Further, the Commission should adopt a change in its rules so that licensees can utilize LEU fuels in lieu of HEU fuels subject to a satisfactory finding under 10 CFR 50.59 and a satisfactory finding by DOE or NRC (perhaps on a generic basis) that such use of LEU fuel will involve no adverse affects to the reactor, its environs, or the public. Every effort must be made by the Commission to assure that its actions in this rulemaking do not lead to intervenor actions, which can be very time consuming and expensive to the licensee. An estimate of the costs to implement the rule (without costs due to intervenors) is set forth in the Appendix.

Recognizing the sensitivity surrounding the utilization of HEU in the international non-power reactor community, GA Technologies has cooperated fully with the NRC, DOE, and other government agencies by developing a fully acceptable LEU fuel that not only replaces HEU TRIGA fuel but can be used in many instances as a replacement for HEU MTR plate-type fuel. We are so confident of the performance of this LEU fuel that we have discontinued the sale of any fuel enriched to greater than 20 percent in U-235 since 1979. End of life demonstration testing of this fuel is continuing under the DOE-sponsored RERTR Program.

We urge you and the other commissioners to consider the many details of the matter under consideration so that undesirable consequences can be forestalled.

Thank you for your consideration of this material.

Yours sincerely,

W L Whittemore

William L. Whittemore
Manager
TRIGA Reactors Facility

HMA:WLW:hc

Attachment:
Appendix A

APPENDIX: Costs to Implement HEU to LEU Core Conversion

It may be useful to point out that industrially owned non-power reactors (five in number) have costs associated with the proposed rule on LEU fuel, some of which are not normally borne by university reactor owners because of their DOE support. On the other hand, these costs are real for all non-power reactor owners and are part of the total costs for the proposed rule.

Item	Cost
i. Core replacement	$1-2M
ii. SAR to support license Amendment (~1 man year)	~100k
iii. License Amendment Fee	41.3k
iv. Shipping HEU core to disposal*	50-75k
v. Reprocessing cost for HEU core.*	≥525k
credit for residual HEU	200k-400k
Total costs	$1.72-2.75M
Credits	$0.200-0.4M

The average cost of about $2M per facility to implement the rule will result in a total cost for this program of about $64M for 31 facilities.

*GA Technologies had direct experience in 1982 with shipping several hundred spent TRIGA fuel elements to burial and/or processing.

GA Technologies

GA Technologies Inc.
PO BOX 85608
SAN DIEGO, CALIFORNIA 92138
(619) 455-2080

HAROLD M. AGNEW
President

19 June 1984

Mr. James K. Asselstine
Commissioner
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Jim:

Following up on today's telephone conversation I am presenting herewith additional material on my concerns about the consequences of the Commission's proposed rule on conversion from HEU to LEU for non-power reactors.

I am quite concerned that this proposed rulemaking will fail in its espoused international objective and through incumbent costs, borne mainly by existing facilities (the order of $1-million or more per facility), will do great harm to the already beleaguered U.S. research community, consisting of government, university, and privately-owned facilities. We further believe that it is an unreasonable policy which causes only NRC licensed facilities, despite costs, to cease their utilization of HEU while no such requirement is mandated upon reactors operated by the government agencies.

It is paramount that NRC's policy for reducing enrichment in existing non-power reactor fuels follow these precepts.

1. Immediate conversion of HEU to LEU should not be required for existing U.S. reactors.

2. If and when a change to LEU is required, it should be done in moderate steps, e.g., at normal refueling periods, upon major facility upgrade involving core redesign, or at construction of a substantially new reactor facility, and

3. Licensees shall not be exposed to significant relicensing processes or associated costs as a result of replacing HEU fuels with LEU fuels to meet a national objective and shall be protected to the extent possible from intervenor actions.

We believe that precepts 1 and 2 should be NRC policy for a number of reasons.

GA Technologies

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HAROLD M. AGNEW
President

19 June 1984

Mr. Frederick M. Bernthal
Commissioner
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Fred:

Following up on today's telephone conversation I am presenting herewith additional material on my concerns about the consequences of the Commission's proposed rule on conversion from HEU to LEU for non-power reactors.

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HAROLD M. AGNEW
President

19 June 1984

Mr. Victor Gilinsky
Commissioner
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Vic:

Following up on today's telephone conversation I am presenting herewith additional material on my concerns about the consequences of the Commission's proposed rule on conversion from HEU to LEU for non-power reactors.

I am quite concerned that this proposed rulemaking will fail in its espoused international objective and through incumbent costs, borne mainly by existing facilities (the order of $1-million or more per facility), will do great harm to the already beleaguered U.S. research community, consisting of government, university, and privately-owned facilities. We further believe that it is an unreasonable policy which causes only NRC licensed facilities, despite costs, to cease their utilization of HEU while no such requirement is mandated upon reactors operated by the government agencies.

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GA Technologies

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(619) 455-2080

HAROLD M. AGNEW
President

19 June 1984

Mr. Thomas M. Roberts
Commissioner
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Tom:

Following up on today's telephone conversation I am presenting herewith additional material on my concerns about the consequences of the Commission's proposed rule on conversion from HEU to LEU for non-power reactors.

I am quite concerned that this proposed rulemaking will fail in its espoused international objective and through incumbent costs, borne mainly by existing facilities (the order of $1-million or more per facility), will do great harm to the already beleaguered U.S. research community, consisting of government, university, and privately-owned facilities. We further believe that it is an unreasonable policy which causes only NRC licensed facilities, despite costs, to cease their utilization of HEU while no such requirement is mandated upon reactors operated by the government agencies.

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I urge you and the other commissioners to consider the many details of the matter under consideration so that undesirable consequences can be forestalled.

Thank you for your consideration of this material. It was good to talk to you and hope to see you out here soon.

Yours sincerely,

Harold

Harold M. Agnew

HMA:WLW:hc

Attachment:
Appendix A

APPENDIX: Costs to Implement HEU to LEU Core Conversion

It may be useful to point out that industrially owned non-power reactors (five in number) have costs associated with the proposed rule on LEU fuel, some of which are not normally borne by university reactor owners because of their DOE support. On the other hand, these costs are real for all non-power reactor owners and are part of the total costs for the proposed rule.

	Item	Cost
i.	Core replacement	$1-2M
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*GA Technologies had direct experience in 1982 with shipping several hundred spent TRIGA fuel elements to burial and/or processing.

142

DOCKET NUMBER PR-50
(49 FR 27769)

(122)

Georgia Institute of Technology
Neely Nuclear Research Center
Atlanta, Georgia 30332
(404) 894-3600

GEORGIA TECH 1885-1985
DESIGNING TOMORROW TODAY

November 2, 1984

'84 NOV -5 P1:58

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Reference: Request for Comments on Proposed Low Enrichment Fuel Policy - 10 CFR Part 50

The recently proposed policy for requiring research reactors to utilize low enrichment fuel will have serious and adverse impact on the operation of the Georgia Tech Research Reactor. I am taking this opportunity to present certain facts which bear on the policy as it would be applied to the GTRR. While I am sure that you are aware of many of these facts, I believe that it is important to present our view of the situation.

(1) Should there be a relicensing requirement, the impact of such a requirement and the subsequent litigations which are sure to follow (the GTRR is located near the center of Atlanta) will convince the upper management of Georgia Tech to close and get rid of the GTRR. I do not think that this stand of closing rather than going through relicensing would be unique to Georgia Tech. Many universities would rather get out. Such an eventuality would deliver a fatal blow to nuclear education, training, man-power development, and research. Is this what NRC wants?

(2) In a recent talk to the ANS meeting in New Orleans, Dr. E. Zebroski of EPRI indicated that future conversion of overseas reactors to low enrichment uranium, may not not affect the existing residual risks associated with the nearly 20 tons of high enrichment uranium already exported. Could it be that, in our haste to set examples for foreign research reactor operators in order to induce them to convert to LEU, we are witnessing a repeat of recent events when President Carter halted research and development on reprocessing and LMFBR development in order to get our friends in Europe and Japan to forego similar development? The results of Mr. Carter's efforts, as everyone knows, were the opposite of what he hoped for and anticipated. Are the NRC commissioners sure that if we convert to LEU others would follow?

Acknowledged by card. 11/6/84
pd

A Unit of the University System of Georgia

Georgia Institute of Technology
Neely Nuclear Research Center
Atlanta, Georgia 30332
(404) 894-3600

GEORGIA TECH 1885-1985
DESIGNING TOMORROW TODAY

(3) If diversion risks exist at research and training reactors in the U.S., such risks can readily be addressed by removing excess unirradiated fuel to "safer" storage facilities. If justifiable concerns can be advanced for tighter security against unauthorized entries into research reactors, it would be far easier and cheaper to design better security systems which would meet the highest of standards. Again I ask, has NRC fully considered these issues or are we rushing into making more rules and regulations before fully understanding the entire impact of these regulations?

(4) It has been rumored that the conversion to LEU would cost $20 million. I also understand that already a sum of $25 million has been spent. Some research reactors have on hand enough fuel to last 15 years. We at Georgia Tech certainly do have enough fuels to last at least 15 years at current levels of usage. The question is why NRC is insisting on conversion "now" when the technology for conversion is not yet developed and the total cost is not really known? I believe it is prudent to use all the available fuel on hand before any change is effected.

In view of the above I would like to emphasize the following:

* Relicensing would certainly force many universities to shutdown their reactors for good. Without relicensing many have closed and some are thinking about closing down shops! The loss of such a resource to the nation would be immense and irreplaceable.

* The perception of risk and the reality of risk are two different things. Let us fully understand what we are doing. Rushing to make rules is easy; making good rules is not.

* The cost of conversion is very high. It would be much cheaper to store unused fuel in "secure" places and improve security measures rather than to force everyone to change to LEU fuels.

I hope reason would prevail at NRC. Thank you for the opportunity to comment.

Sincerely,

R.A. Karam

R.A. Karam
Interim Director
Nuclear Research Center

RAK/jlr

[redacted] [redacted]

EPRI
Electric Power
Research Institute

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(125)

Vol. 2

'84 NOV -5 A9:[illegible]

November 2, 1984

Secretary of the Commission
U.S. Nuclear Regulatory Commission
1717 H Street, N.W.
Washington, D. C. 20555

Subject: Comments on Proposed Rule on Conversion of HEU-LEU

Dear Sir:

Attached is a letter giving my response to questions from the House Science & Technology Commission Chairman.

These replies also serve as my comments on the proposed rule.

Sincerely,
E. L. Zebroski (nw)
E. L. Zebroski
Chief Nuclear Scientist

ELZ/nw
attachments

Acknowledged by card 11/6/84
pd

DOCKET NUMBER PR-50
PROPOSED RULE PR-50
(49 FR 27769) (117)

**UNION OF
CONCERNED
SCIENTISTS** 1346 Connecticut Avenue, N.W. • Suite 1101 • Washington, DC 20036 • (202) 296-560

'84 [illegible] -2 P12:26

November 2, 1984

Docketing and Service Branch
Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Re HEU Conversion of nonpower reactors
(Proposed rule, 49 FR 27769)

The Union of Concerned Scientists wishes to be recorded as strongly supporting this rule as proposed by the Commission. Its adoption would represent a modest, but nonetheless important, step toward reducing the availability of weapons-grade materials not only in this country but (through example) around the world.

The proposed rule takes a fair, balanced and quite patient approach toward mandating the conversion of nonpower research and test reactors from highly enriched uranium (HEU) to low enriched uranium (LEU). We would perhaps prefer a more strict rule, mandating such conversion within a time certain subject only to the availability of acceptable alternative fuel. But we understand (although we do not fully endorse) the real-world reasons why the Commission proposes to include "financial support" (i.e. government subsidies) among the factors to be considered in assessing each licensee's fuel replacement schedule. Given that concession, we certainly do not see any reason to insert any exceptions in the rule as proposed.

Adoption of this rule would further a consistent U.S. nonproliferation policy and demonstrate that this country is serious about reducing the risks associated with the use of nuclear technology. UCS urges the Commission to speedily adopt a final rule no less stringent than that proposed.

Respectfully submitted,

Michael E. Faden

Michael E. Faden
Legislative Counsel

Acknowledged by card 11/2/84
pd

DOCKET NUMBER PR-50 (126)
PROPOSED RULE (49 FR 27769)

LA 84-109

DOCKETED

'84 NOV -7 A11:07

OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

Westinghouse Electric Corporation

Water Reactor Divisions

Box 355
Pittsburgh Pennsylvania 15230

November 2, 1984

Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Docketing and Service Branch

Dear Sir:

The purpose of this letter is to comment on the 10 CRF 50 proposed rule, Limiting the Use of Highly Enriched Uranium at Research and Test Reactors. In particular, I would like to comment on the ramifications of applying this proposed rule to the Westinghouse Nuclear Training Reactor (WNTR). The WNTR has been located at the Westinghouse Nuclear Training Center, Zion, Illinois, since 1971. During the past 13 years, the WNTR has been fully dedicated to the initial and requalification training of licensed nuclear power plant operators. For many students, the NTR provides initial reactor startup and operational experience and first-time application of the theoretical concepts associated with operating a large light-water reactor. Students are able to focus on such topics as subcritical multiplication, neutron kinetics, reactor dynamics, nuclear instrumentation, and design and inherent reactivity effects; topics that are often difficult to highlight when teaching large plant, integrated operations. Approximately 150 students are trained each year by the NTR staff. Student evaluations of the training programs have been consistently positive, with most students emphasizing their better understanding of theoretical operational concepts.

Westinghouse Electric Corporation, licensee of the Westinghouse Nuclear Training Reactor, generally opposes the conversion of the WNTR HEU fuel to LEU fuel for the following reasons:

> The WNTR fuel is lifetime core with a unique concentric-ring fuel design. Replacement cost for this type of fuel was not quantitatively considered in the "Regulatory Analysis of Limiting the Use of High-Enriched-Uranium (HEU) in Domestic Non-Power Research Reactors (10 CFR Part 50)" and availability of LEU fuel for this design has not been determined. If a supplier for this fuel is not available, then a significant reactor design would be required to accomodate a new fuel type. A new core and core support mechanisms would further require writing and evaluation of new technical specifications, writing and evaluation of new student experiments, and training of all staff. Even assuming new fuel manufacture costs are paid by the American taxpayer, the engineering, licensing, training, and lost time costs associated with a major redesign and testing program may be prohibitive for Westinghouse.

Acknowledged by card 11/8/84 pd

> The operation of the WNTR poses no undue risk to the public health and safety. The present NRC approved Security Plan uses not only internal procedures but also local government law enforcement agencies to assure that the fuel is constantly protected from theft or diversion.
>
> Converting the HEU fuel currently used in the WNTR to LEU could preclude completion of required training programs conducted for the nuclear power utilities. Furthermore, the manpower necessary to either refuel, redesign, or decommission the NTR is very much needed to meet the increasing training needs of the nuclear industry.

Westinghouse is interested in maintaining the NTR and its contribution to the quality performance of the nuclear industry. In order to minimize safeguards concerns, Westinghouse recently complied with NRC regulations and reduced the NTR HEU fuel inventory. This seemingly straightforward fuel change required us to shut down the NTR for a period of four (4) months, and incur administrative, engineering, and capital costs of approximately $200K, a figure considerably higher than the value of the original fuel assemblies. The impact on our manpower availability and our ability to meet our commitments to the utility population was significant. Also, the flexibility of our program, i.e., the number of teaching experiments, was reduced.

In theory, the training programs conducted at the WNTR could be performed with low enriched fuel. At this point, however, it is not clear that a low-enriched fuel element design is available or feasible for the NTR core. Consequently, the expenditure of manpower and the costs associated with a complete refueling and possible core redesign is expected to be much greater than our previous expenditures. Should implementation of the current proposed rule result in similar or greater costs, cause a more extensive drain on our available manpower, or further reduce our operating flexibility, we face the likely prospect of decommissioning the NTR.

We appreciate your consideration of our concern regarding the conversion of HEU fuel to LEU fuel for the Westinghouse Nuclear Training Reactor.

A Joseph Nardi

A. J. Nardi, Manager
NES License Administration

AJN/jh

146

MICHAEL D. BARNES
8TH DISTRICT, MARYLAND

ASSISTANT MAJORITY WHIP

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MONTGOMERY COUNTY OFFICE:
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WHEATON, MARYLAND 20902
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TTY-(301) [illegible]

COMMITTEE ON FOREIGN AFFAIRS
CHAIRMAN,
INTER-AMERICAN AFFAIRS
MEMBER, HUMAN RIGHTS AND
INTERNATIONAL ORGANIZATIONS

COMMITTEE ON THE DISTRICT
OF COLUMBIA
MEMBER, GOVERNMENT OPERATIONS
AND METROPOLITAN AFFAIRS
MEMBER, JUDICIARY AND
EDUCATION
CHAIRMAN,
FEDERAL GOVERNMENT SERVICE
TASK FORCE

Congress of the United States
House of Representatives
Washington, D.C. 20515

'84 NOV -8 P1:33

November 2, 1984

DOCKET NUMBER
PROPOSED RULE PR-50
(49 FR 27769)

(127)

Mr. Samuel J. Chilk
Office of the Secretariat
Docketing and Service Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Chilk:

I am writing to support the proposed NRC rule to require NRC-licensed research reactors to convert from highly enriched uranium (HEU) to low enriched, non-weapons usable uranium fuels.

The conversion of our domestic, NRC-licensed research reactors will help demonstrate that the U.S. is willing to set the standard in the conversion of reactors to safer fuels. A good U.S. example will become increasingly important in convincing other nations to convert their reactors to safer fuels.

In addition, implementation of the proposed rule would help reduce the future threat of terrorism within the U.S. by reducing the amount of HEU in circulation. While at present NRC-licensed research reactors do not appear to be likely targets of terrorist groups, it is clear from past acts by international groups, as Commissioner Bernthal noted recently in Congressional testimony, "that a threat can materialize without sufficient warning from intelligence sources."

I appreciate having the opportunity to express my views in support of the NRC-proposed rule.

Sincerely,

Mike Barnes

Michael D. Barnes

11/8...To EDO for Appropriate Action
Cpys to: RF, OCA to Ack..84-1063

MDB/lo

17

Congress of the United States
House of Representatives
Washington, D.C. 20515

November 2, 1984

'84 NOV -8 P1:33

BRANCH

Mr. Samuel J. Chilk
Office of the Secretariat
Docketing and Service Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Chilk:

This is to express our strong support for the proposal to require the replacement of highly enriched uranium (HEU) fuel in research reactors licensed by the Commission with low enriched uranium (LEU) fuel. We urge the adoption of the proposed NRC rule that would implement that proposal. We firmly believe that the use of a nuclear explosive material, such as HEU, as a reactor fuel poses significant and unnecessary risks that must be avoided where possible.

The elimination of HEU from research reactors in the United States is clearly in the national interest as it will directly reduce the possibility of theft and misuse of this material and the likelihood of terriorist acts against facilities where it is being used.

Moreover, the conversions which would take place under the rule would set an important international example and establish U.S. leadership in the conversion of research reactors throughout the world to non-explosive fuels. The proposed rule is clearly in the non-proliferation and international security interests of the United States and of the world as well.

In view of these public benefits we believe Congress will continue to provide funds not only to complete the development of reduced enrichment fuels but to defray the cost of its use in university research reactors as well.

The Commission is to be commended for its initiative in this important area.

Sincerely,

Richard Ottinger
Richard L. Ottinger, Chairman
Subcommittee on Energy
Conservation and Power
Committee on Energy and Commerce

Ed Markey
Edward J. Markey, Chairman
Subcommittee on Oversight and
and Investigations
Committee on Interior and
Insular Affairs

DOCKET NUMBER
PROPOSED RULE PR-50 (129)
(49 FR 27769)

148

UNIVERSITY OF MISSOURI

Research Reactor Facility

Research Park
Columbia, Missouri 65211
Telephone (314) 882-4211

November 6, 1984

'84 [illegible] -9 P2:50

Secretary of the Commission
Attention: Docketing and Service Branch
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Subject: Proposed Rule on limiting the Use of
Highly Enriched Uranium in Domestic
Research and Test Reactors (49FR27769)

Gentlemen:

In response to the Federal Register notice of July 6, 1984 (49FR27769-27772), the University of Missouri Research Reactor (MURR) wishes to make the following comments in addition to the comments submitted in earlier correspondence.

MURR fully supports the basic goal of the proposed rule - minimizing the risk of diversion of highly enriched uranium (HEU). However, the proposed rule would go beyond a reasonable cost/benefit ratio because eliminating the HEU at non-power research and test reactors (NPR's) licensed by the U. S. Nuclear Regulatory Commission (NRC) will not significantly reduce the overall proliferation risk. Gains could be made at a much reduced cost to benefit ratio if the proposed rule was modified.

The following changes should be made to the rule:

1. 50.64(c)(2)(i) Acquire no additional HEU fuel if LEU fuel acceptable to the Commission for that reactor is available at the time of the proposed acquisition of the HEU fuel by the licensee and the license changes have been complete for the use of LEU with DOE providing the funds for the license changes.

   50.64(c)(2)(ii) Delete this paragraph.

Acknowledged by card 11/9/84 pd

Converting NPR's which have lifetime cores should not be put in the regulation for several reasons. First, as stated by Edwin L. Zebroski of EPRI in a paper titled "Relative Diversion Exposures of High Enrichment Uranium: Relation to University Research Reactors" at the June 4, 1984 New Orleans ANS meeting, "The characteristics of U. S. university research reactors appear to be in the lowest level of four categories of diversion risks." The research reactors with lifetime cores operate with amounts of U-235 which are insufficient to make a practical nuclear device. It would take the U-235 from several of them to be sufficient to make a workable nuclear device and that is including the fuel in the cores which normally is self-protecting as per 10CFR73.60. Second, this goes beyond what the U. S. Department of State is wanting from the foreign reactors. Setting a good example for foreign reactors has been given as justification for this rule, but setting an example we do not expect them to follow is just a futile exerise. Third, the foreign reactors see the conversion of the small research reactors as an insignificant gesture with very little affect in reducing proliferation risk of HEU in the United States.

2. 50.64(c)(3) If not required by paragraphs (c) (1) and (2) of this section to use LEU fuel, the applicant or licensee must use HEU fuel of as high a uranium loading and enrichment as is available and acceptable to the Commission but not in excess of a lifetime core.

This change would do more to reduce the risk of diversion of HEU than the NRC proposed 50.64(c)(3). In fact the NRC proposed rule would increase the risk of diversion of HEU associated with some NPR's due to an increase in number of HEU fuel shipments. As stated in the Edwin Zebroski report the risk of diversion is greater for HEU fuel being transported than for HEU at a university reactor. The usable U-235 in a fuel cycle is the excess grams in the fuel element greater than the amount required to be critical with equilibrium xenon and control rods out of the core. It takes 1.26 gram U-235 per megawatt-day of energy produced. For a given annual operating cycle the number of grams of U-235 burned up is nearly independent of the enrichment, however the ratio of total U-235 needed in the core per usable U-235 increases as the enrichment decreases for a given uranium density. In fact it goes to infinity when the usable grams go to zero.

Therefore the proposed rule would require the higher performance NPR's, which already use fuels with uranium densities as high as is currently available and proven to safely operate at high power densities, to increase the amount of HEU fuel they use. For example, MURR fuel elements are loaded at 1.72 gm/cc uranium density. At this density the enrichment could be reduced to 80% if it were available. With 80% enrichment a core would last approximately 40 hours - from cold clean start-up till equilibrium xenon is reached. This fuel cycle would require several hundred fuel elements per year or more, depending on how many times you were willing to reload the core and operate the reactor with an increasingly shorter operating cycle each time due to fuel burnup (.525 gm/hr). This corresponds to between 240 Kg to 1240 Kg (core being used from 8 times to only once) U-235 needed for the fuel cycle each year versus the currently required 18.6 Kg. The current regulation limiting the number of HEU shipments in progress in the United States to one at any time makes the transportation diversion risk insignificant. However, disregarding the fact that MURR could not afford the operating cost associated with the 80% enriched HEU fuel cycle, it would require at least 50 shipments a year for MURR. This would be impossible to accomplish with the current carriers even if there were no other shipments of HEU in the United States.

A better alternative is to use the new higher uranium density fuel technology being developed at Argonne and Idaho to achieve as high a U-235 loading as possible. With this approach the goal of reducing the risk of diversion of HEU can be achieved with a net fuel cycle savings instead of an increased cost. Therefore with higher U-235 loading, e.g. highly enriched and high density uranium, the total kilograms of U-235 in the fuel cycle goes down. The decrease shows up in a lower amount of HEU needed at the reactor at any one time and a decrease in the total number of kilograms of HEU shipped to and from the reactor. In fact, the benefit can be doubled. If the fuel elements are mixed often enough, the usable U-235 is almost doubled. Additionally, the fuel elements at the NPR's that cannot use LEU are very self-protecting (10CFR73.60) due to the high power densities. At MURR the dose rate for fuel elements in cycle is greater than 50,000 R/hr at three feet in the air and for spent fuel waiting to be shipped is greater than 2,000 R/hr. Additionally, with more megawatt-days per core the radiation level at time of shipment would increase thereby adding to the self-protection. The enrichment in the spent fuel would also be decreased.

MURR feels the goal to minimizing the diversion risk of HEU is adequately met by current regulations and the recently revised and NRC approved security plans at the NPR's. It is our opinion the NRC agrees with this or the proposed rule would not be contingent on funding from DOE. Therefore, our first priority is to not make unnecessary new regulations that hurts the health and safety of the public by diverting funds and staff time away from the primary goal of making advancements through research. However, if the decision is made to put new requirements on the use of HEU, the above changes to the proposed rule would do more to reduce the diversion risk of HEU at a lower net cost than the rule published in the Federal Register.

Sincerely,

J C McKibben

J. C. McKibben
Reactor Manager

Reviewed and Approved:

Don M. Alger

Don M. Alger
Associate Director

PR-50 (129)
(49 FR 27769)

DOCKETED

11:12

November 17, 1984

Office of the Secretary
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Docketing and Service Branch

Dear Sir:

I am writing to support the NRC proposed rule to require the conversion of NRC-licensed non-power reactors from highly enriched uranium (HEU) to low enriched uranium (LEU) fuels.

I commend the Commission for proposing the rule and agree with its objective to reduce the amount of HEU in circulation within the United States and to encourage foreign non-power reactor owners to do the same in their own countries.

I have attached Congressional testimony I recently wrote in support of the proposed rule that lists several benefits to be gained by implementing it. One additional comment involves an exception to the proposed rule which would allow non-power reactors to use HEU if the facilities unique purpose cannot be accomplished without the use of HEU. I am concerned that the exemptions could become routine. In order to avoid this possibility, the NRC should show how unique the purposes might be by requiring open hearings.

Converting research reactors from HEU to LEU fuel even in the best of circumstances will take several years. Consequently, the Commission should complement the proposed rule with a policy that will reduce the inventories of non-self protecting HEU at non-power reactors. At present NRC-licensed non-power reactors do not appear to be a likely target of terrorist groups. But, it is clear from past acts by international terrorist groups, as Commissioner Bernthal noted recently in Congressional testimony, "that a threat can materialize without sufficient warning from intelligence sources."

In regard to such a policy, I have also attached an article I wrote that discusses the current physical protection requirements for HEU. While I do not believe that the existing physical protection limits should be changed at this time, I do argue that they should be supplemented with a policy similar to the ALARA standard in radiation protection that would require that the amount of HEU at a particular facility be kept "as low as reasonably achievable." All amounts of HEU carry some risk of being diverted. Since lower amounts of HEU mean lower risk to the public, then as a matter of policy, the amounts of HEU

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should be kept "as low as reasonably achievable." If the risk can be reasonably set at zero, it should be done and the use of HEU avoided. Such a policy would make it easier to reduce inventories of HEU at facilities, could be implemented more quickly than a fundamental change in physical protection requirements, and would create a process that could cope with the inevitable increase in the future nuclear weapons skills and capabilities of terrorist groups or clandestine national programs that someday might try to divert enough HEU to make a nuclear explosive.

Thank you for the opportunity to comment of the proposed rule.

Sincerely,

David Albright

David Albright

Attachments

David Albright
FEDERATION of AMERICAN SCIENTISTS
307 MASSACHUSETTS AVE. N.E. WASHINGTON DC 20002

The Amount of Weapon-Grade Uranium Needed to Construct a Nuclear Explosive:

Are the Current Physical Protection Requirements Adequate?

By
David Albright
Federation of American Scientists

November 17, 1984

DRAFT

The Nuclear Regulatory Commission (NRC) is trying to decide whether to require the conversion of non-power reactors from highly enriched uranium (HEU, containing more than 20 percent uranium-235) to low enriched uranium fuels. Most participants in this debate agree that the inventories of HEU should be reduced. However, there is considerable disagreement about what quantity of HEU presents a significant risk. At issue is the amount of HEU required by a terrorist or national group to make a nuclear explosive. Also in question is the appropriate threshold quantity of HEU, above which maximum amounts of physical protection must be provided.

Highly enriched uranium can be used directly in nuclear weapons, and thus, is more of a proliferation risk than less enriched uranium. According to a General Accounting Office report, State Department and Arms Control and Disarmament Agency officials concluded in 1978 that:

> "a single seizure of a significant quantity of HEU by an irresponsible government or terrorist group could have profound repercussions for the security of all nations and would almost certainly have a highly negative impact on all peaceful nuclear activities to the detriment of all nations. Furthermore, the officials said that the dangers are not limited to material located in irresponsible nations. They said that an irresponsible nation, or a sub-national group, might seize material from the territory of the most responsible nation." (GAO, 1982, p. 4)

According to former nuclear weapons designer Ted Taylor, the perception that nuclear weapons are too technically complex to be constructed by terrorist or inexperienced national groups no longer exists, because such weapons have in fact been built and much of the necessary technical information is now declassified (Willrich, 1974, pp. 5-6). Some of Taylor's conclusions have been criticized, but a number of his critics do admit that the above conclusion is reasonable, if the weapons in question use highly enriched uranium (Meyer, 1977, p. 434).

NRC physical protection requirements contain a threshold amount above which HEU requires substantially more protection. Briefly, the minimum objective of this policy is that thefts from a single facility which has over 5 kilograms of uranium-235 contained in non-self protecting* HEU must be detected and prevented, while thefts from a facility which has under 5 kilograms must be detected and responded to, but not necessarily prevented.

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* radiation exposure is less than 100 rem per hour at 3 feet from material.

The Department of Energy has stated that more than one theft equal to 5 kilograms of uranium-235 contained in HEU would be required to construct a clandestine fission explosive. According to Taylor, who designed the largest and smallest yield fission bombs, the amount of HEU required to make a nuclear explosion is not a well-defined number (Taylor, 1984). It depends on the design of the bomb, i.e. whether it is an implosion or gun-assembly explosive, the enrichment of the HEU, the type and amount of neutron-reflecting material surrounding the HEU, the shape of the HEU, the type and quality of the equipment and facilities available to the weapons designers, and, most important of all, the talents, needs, and experience of these designers (Willrich, 1974). Consequently, any determination of this quantity must combine basic weapon physics with an evaluation of the technical difficulty a terrorist group or clandestine national program would face in actually constructing a nuclear device. A detailed analysis would necessarily involve highly classified information, but a rough, "first order" analysis can be done using only publicly available information, sufficient for making some general conclusions about the physical protection issues discussed above.

The critical mass of HEU when it is surrounded by neutron-reflecting materials is listed in various publications. Using beryllium as a reflector produces the lowest critical masses of HEU that are contained in the unclassified literature (Paxton, 1975). If the beryllium reflector is 4.6 inches thick, the critical mass of a uniform, spherical piece of weapon-grade uranium (enriched to about 94 percent uranium-235) metal is about 13 kilograms of uranium-235 (Paxton, 1975, p. 13). If the thickness of the beryllium is only 1.9 inches, then the critical mass of the HEU metal enriched to 94 percent is about 22 kilograms of uranium-235 (Paxton, 1975, p. 13). If instead of beryllium, natural uranium is used as a reflector, then a sphere of 94 percent HEU metal has a critical mass of about 19 kilograms of uranium-235 when it is surrounded by about 4 inches of natural uranium and about 25 kilograms of uranium-235 when it is surrounded by 1.75 inches of natural uranium (Paxton, 1975, p. 8).

A nuclear weapon cannot be only critical. It must be sufficiently supercritical or contain enough additional uranium-235 to produce an explosion. The pressures that develop in a nuclear explosive are so large that the core will rapidly expand to a subcritical configuration. Obtaining an effective explosion depends on whether the fission reaction is stopped by these pressures before an appreciable fraction of the uranium-235 has fissioned. Surrounding the HEU by a reflector also serves to hold the core together longer which increases the yield. As a result, the reflector is often called a tamper.

The amount of HEU over one critical mass necessary to produce an explosion is classified. It is clear, though, that assembling one critical mass is not enough to make an explosion, two critical masses is enough for an explosion with a yield equivalent to several hundred tons of high explosives (Foster, 1970, p. 521), and three critical masses is probably enough for a high yield explosion. Assembling one critical mass or slightly above this amount would produce intense radiation within the immediate area. An inefficient, low-yield explosion could be obtained with more than one but less than two critical masses. These low yield weapons also present a great danger, particularly from their radiation effects. The radiation from the detonation would be lethal out to a larger distance than its blast effects (Willrich, 1974, table 2-1). Even a nuclear explosive that has a yield equivalent to only one ton of high explosive would produce enough neutron radiation to deliver fatal doses to people within about 120 meters of the blast, but would produce moderate blast damage (3 psi) out to only about half that radius (Willrich, 1974, table 2-1). For the purposes of this discussion, it is assumed that an explosion can be achieved with between one and two critical masses, although it is understood that assembling between one critical mass and some unknown amount greater than one critical mass will produce effectively zero yield.

There are two basic types of nuclear explosive designs that are used to achieve a supercritical mass - the gun-type and the implosion-type device. In a gun-type bomb two subcritical masses of fissionable material are brought together into a supercritical mass. The bomb detonated over Hiroshima at the end of World War II was a gun-assembly explosive that contained 60 kilograms of uranium enriched to over 90 percent (McPhee, 1974, p. 14). In order to assemble between one and two critcal masses of uranium-235 contained in weapon-grade uranium and surrounded by the neutron reflectors discussed earlier, a designer would need between 13 and 50 kilograms of uranium-235.

The implosion design involves surrounding a subcritical mass of fissionable material by chemical high explosives. If the explosives are uniformly detonated, then they produce an ingoing shock wave that strikes the fissionable material and provides the necessary compression to produce a supercritical mass. The implosion design requires considerably less HEU than the gun assembly design. When a sphere of HEU of uniform density surrounded by a reflector assembly is uniformly compressed, the critical mass of the compressed HEU is proportional to the inverse of the square of its density. The chemical explosion in an implosion-type nuclear weapon will be assumed to be capable of doubling the density of the HEU in the core. Thus, when a spherical core of HEU and a combined reflector and tamper that is initially only one quarter of its critical mass is compressed to twice its initial density, it will correspond to one critical mass. When using the four neutron reflectors considered above, doubling the density of the HEU metal lowers the critical mass to only 3.3 to about 6.3 kilograms of uranium-235. With the thick beryllium reflector considered earlier, 3.3 to 6.6 kilograms of uranium-235 are required to assemble one to two critical masses. Similarly, with the thin natural uranium reflector, 6.3 to 12.6 kilograms of uranium-235 are required.

Presently, it appears doubtful that a terrorist group could build a device that doubles the density of the core, but it is possible for an inexperienced national program. Whether an inexperienced designer could obtain significantly more than a twofold increase in density requires a more sophisticated analysis than the one presented in this paper. Clearly, increasing the density of the HEU in the core by a factor of three or four rather than a factor of two will require a much more sophisticated implosion design, because it becomes increasingly difficult to further compress the metal. This results not only from the metal's increasing resistance to further compression, but also to the outward pressures produced by the initiation of the fission reaction.

Groups wanting to construct an explosive from HEU will require larger amounts than just the amounts stated above. Some of the HEU will be lost during the processing of the HEU into metal and its fabrication into bomb parts. However, it is reasonable to assume that process losses will probably not exceed 10 to 20 percent of the original amount.

Using the reflectors considered above and the assumptions made in this report, an implosion design could be constructed with a yield equivalent to several hundred tons of high explosive from roughly 8 to 15 kilograms of weapon-grade uranium. Under the same conditions lower yield weapons could be constructed with smaller amounts of HEU, perhaps as low as 5 kilograms of weapon-grade uranium.

It is highly unlikely that either a terrorist or inexperienced nation could construct a nuclear explosive with less than 5 kilograms of weapon-grade uranium. However, this very rough analysis suggests that an inexperienced national program might be able to produce a low yield explosion with between 5 and 10 kilograms of weapon-grade uranium. As a result, it is arguable whether adequate conservatism is built into the existing physical protection limits.

Moreover, the current physical protection limits do not allow for simultaneous thefts from a few facilities. Because 5 kilograms of uranium-235 is the limit between very stringent physical protection requirements and lesser requirements, an incentive exists to store somewhat less than 5 kilograms of HEU, which has indeed happened at university research reactors. But enough HEU to construct an explosive could be stolen from only a few of these facilities, each of which contains less than 5 kilograms of uranium-235.

The most difficult part of any analysis to determine the amount of HEU required to make a nuclear explosive is to estimate the capabilities of the groups which might divert HEU and actually build a nuclear explosive. All conclusions about the amount of HEU required to make an explosive result from an analysis of the present capabilities of terrorist and national groups to make such a device. Their future capablities will most likely increase and the extent of that increase is the largest uncertainty in any estimate of the amount of HEU necessary to make a nuclear explosive.

The current physical protection requirements need to be strengthened. Instead of lowering the current physical protection limits, a more fruitful approach would be to supplement them with a policy similar to the "as low as reasonably achievable" (ALARA) criterion in radiation exposure. All amounts of HEU carry some risk of being diverted. Since lower amounts of HEU mean lower risk to the public, then as a matter of policy, the amounts of HEU should be kept "as low as reasonably achievable." If the risk can be reasonably set at zero, it should be done and the use of HEU avoided. Such a policy would make it easier to reduce inventories of HEU at facilities, could be implemented more quickly than a fundamental change in physical protection requirements, and would create a process that could cope with the inevitable increase in the future nuclear weapons skills and capabilities of terrorist groups or clandestine national programs that someday might try to divert enough HEU to make a nuclear explosive.

An ALARA approach to the permissible amount of HEU at a facility is not limited to facilities that contain relatively small amounts of HEU or, in fact, to just HEU. It could just as easily be applied to facilities that use plutonium or large amounts of HEU. In each case an analysis could be done that seeks to keep the amount of these materials as low as reasonably achievable.

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(49 FR 27769)

AMERICAN NUCLEAR SOCIETY
VIRGINIA SECTION

CHARTERED SEPTEMBER 26, 1956

84 NOV 23 P2:33

BRANCH

November 19, 1984

Reply To:

C. T. Rombough
P.O. Box 10935
Lynchburg, Va. 24506-0935

Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTN: Docketing and Service Branch

Dear Mr. Secretary:

Proposed Rule on Limiting the Use of Highly Enriched Uranium in Domestic Research and Test Reactors

Reference: J. M. Hendrie, President of the American Nuclear Society to the NRC Secretary, same subject, dated October 22, 1984.

It has been brought to my attention that the Commission may be considering the above proposed rule based not on the technical facts, but rather on the number of letters received which are pro or con. Is this true? If it is, then the health and safety of the public is indeed in jeopardy. I could easily create several thousand "individual" letters which say essentially the same thing as our President and spokesman has already said in reference 1 (attached). Dr. Hendrie represents the American Nuclear Society, which is composed of over 14,000 professional scientists and engineers who happen to know what they are talking about. But to require these individuals to write the same letter that Dr. Hendrie has written is absurd. The Commission should be basing its decisions on the technical merits of the question, not public opinion. Why? Because if Einstein (or some other eminently qualified individual) has the correct answer, we need only ask him. Just because he did not go to the trouble of garnering 100,000 laymen to agree with him is irrelevant - the answer stays the same.

The anti-nuclear folks are well trained in the art of mass mailings and obstructionism. To require the nuclear experts to resort to the same tactics to present their views is illogical, unnecessary, and ridiculous.

Sincerely,

Charles T. Rombough

Dr. Charles T. Rombough
Chairman, Virginia Section
American Nuclear Society

CTR:mlj

c: VANS
J. M. Hendrie

NRC Commissioners
B. Paige
L. Wallis
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